AD NUMBER

AD903982

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; AUG 1972. Other requests shall be referred to Aeronautical Systems Division, ATTN: YBT, Wright-Patterson AFB, OH 45433.

AUTHORITY

ASD ltr dtd 11 Apr 1975

FTC-TR-72-33

AD INEXPLORATA

CATEGORY II
FB-111A RELIABILITY AND MAINTAINABILITY EVALUATION

AFFTC

NEAL F. CHAMBLEE
Mathematician

JAN M. HOWELL
Reliability and Maintainability Engineer

TECHNICAL REPORT No. 72-33

SEPTEMBER 1972

Distribution limited to U.S. Government agencies only (Test and Evaluation), August 1972. Other requests for this document must be referred to ASD (YBT), Wright-Patterson AFB, Ohio 45433.

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

ERRATA SHEET
FTC-TR-72-33

CATEGORY II
FB-111A RELIABILITY AND
MAINTAINABILITY EVALUATION

The following pen and ink changes should be made to this report:

Page 53, Table XXXII

1. Column 5, Row 9
   Change 1.3 to 1.2

2. Column 3, Row 10
   Change 10.1 to 20.6

3. Column 4, Row 10
   Change 0.6 to 2.1

4. Column 5, Row 10
   Change 10.7 to 22.7

FTC-TR-72-33

CATEGORY II
FB-111A RELIABILITY AND MAINTAINABILITY EVALUATION

NEAL F. CHAMBLEE
Mathematician

JAN M. HOWELL
Reliability and Maintainability
Engineer

FOREWORD

This report presents the results of the reliability and maintainability analyses conducted during the FB-111A Category II test program. The FB-111A Category II flight test program was initiated by an Air Force Flight Test Center Project Directive 67-1, dated 13 July 1966. The flying portion of the program was accomplished between 31 August 1968 and 27 June 1972.

A major contribution to the FB-111A reliability and maintainability analysis was made by Senior Master Sergeant Earl H. Wilson, NCOIC, F-111 Joint Test Force Maintenance Analysis.

Foreign announcement and dissemination by the Defense Documentation Center are not authorized because of technology restrictions of the U.S. Export Control Acts as implemented by AFR 300-10.

Prepared by:

Neal F. Chamblee

NEAL F. CHAMBLEE
Mathematician

Jan M Howell

JAN M. HOWELL
Reliabilit" and Maintainability Engine r

Reviewed and approved by:
6 September 1972

Jack W Gillette

JACK W. GILLETTE
Colonel, USAF
Director, F-111 Test Force

James W Wood

JAMES W. WOOD
Colonel, USAF
Commander, 6510th Test Wing

Robert M. White

ROBERT M. WHITE
Brigadier General, USAF
Commander

ABSTRACT

This report presents the results of the reliability and maintainability evaluation conducted during the FB-111A Category II test program. The aircraft demonstrated a 1.6-hour mean time between failures and a 1.5-hour mean time between aircrew writeups. The overall aircraft reliability was significantly degraded by the low reliability of the flight controls and most avionics subsystems. The reliability of most non-avionics subsystems was acceptable. The contractor predicted that 23.8 maintenance manhours per flying hour would be required, and 48.0 manhours were actually measured; the difference was attributed to low reliability. Except for excessive removal, bench check, and replacement of good components during troubleshooting, the maintainability of the FB-111A was good. The mode/status lights associated with some subsystems were of questionable value in detecting failures correctly.

table of contents

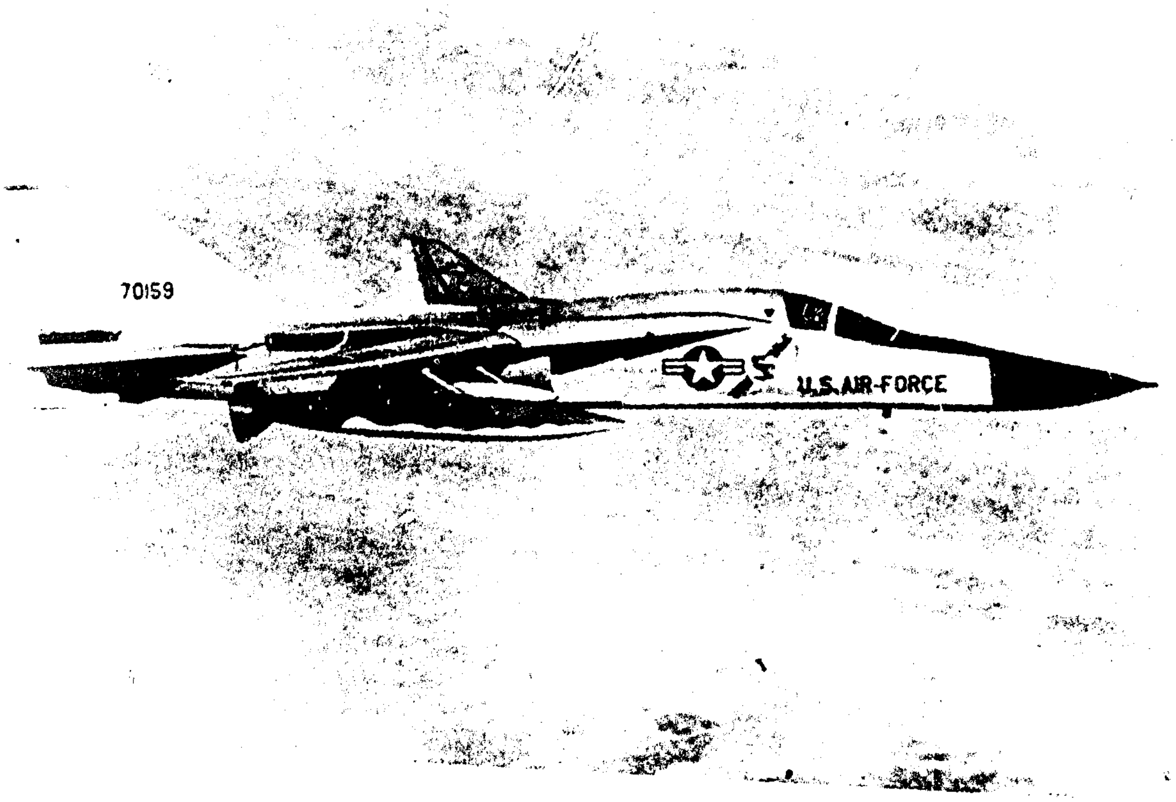
list of illustrations

list of tables

list of abbreviations and symbols

Item	Definition	Units
AGE	aerospace ground equipment	- - -
AH/MON	active hours per month that the aircraft was available for flying and/or maintenance	hrs per mo
A_i	inherent aircraft availability	pct
CND	could not be duplicated or cannot duplicate	- - -
D	maximum absolute difference between theoretical distribution and sample distribution	dimensionless
DOME	distribution of maintenance events	- - -
ECP	Engineering Change Proposal	- - -
ECS	environmental control system	- - -
ETI	elapsed time indicator	hrs
FFS	formatted file system	- - -
FH	flight hours	- - -
FH/MON	flight hours per month	hrs per mo
FLT/FH	number of flights per flight hour	$hour^{-1}$
f(t)	probability density function	dimensionless
F(t)	cumulative distribution function	dimensionless
GFAE	government-furnished aeronautical equipment	- - -
GPC	general purpose computer	- - -
IFF	identification friend or foe	- - -
ILAS	instrument landing approach system	- - -
INS	inertial navigation system	- - -
IRU	inertial reference unit	- - -
K-S	Kolmogorov-Smirnov	- - -
LCL	lower confidence limit	- - -
LRU	line replaceable unit	- - -
M_{MAX}	90th percentile (time to repair)	- - -
AMPT/PI	mean active hours required to complete a phase inspection	hrs
MART/Flt	mean active hours to repair the aircraft between successive flights	hrs
median	50th percentile	- - -
MFHBA	mean flight hours between aborts	hrs

Item	Definition	Units
MFHBFD	mean flight hours between function degradations	hrs
MFHBFL	mean flight hours between function losses	hrs
MMH	maintenance manhours	hrs
MMH/FH	maintenance manhours per flying hour	- - -
MTBF	mean time between failures	hrs
N_a	number of aborts recorded against the subsystem	- - -
NCU	navigation computer unit	- - -
N_d	number of functional degradations recorded against the subsystem	- - -
N_f	number of functional losses recorded against the subsystem	- - -
N_s	number of successful missions recorded against the system	- - -
PI/FH	number of phase inspections per flight hour	$hour^{-1}$
P_{na}	probability of no aborts	dimensionless
P_{nd}	probability of no function degradation	dimensionless
P_{nf}	probability of no function loss	dimensionless
R&M	reliability and maintainability	- - -
R/T	receiver-transmitter	- - -
SEDS	Systems Effectiveness Data System	- - -
t	time	hrs
TFR	terrain following radar	- - -
TTAR	time to turn around	hrs
WUC	work unit code	- - -
α	acceptable risk level (10 percent, 1-confidence level = 1-.90)	pct
θ	exponential probability distribution parameter	dimensionless
θ_1, θ_2	Weibull probability distribution parameters	dimensionless
μ, σ^2	log normal probability distribution parameters	dimensionless
χ^2	critical value for chi-square distribution with risk α; and degrees of freedom $2 N_f + 2$	dimensionless


70159
U.S. AIR FORCE

INTRODUCTION

GENERAL

The FB-111A Category II systems test program began in August 1968 when FB-111A USAF S/N 67-159 was delivered to the AFFTC. The test program was extended to allow for aircraft subsystem updates and the delay caused by a wing inspection and modification program. The AFFTC was responsible for conducting the test program under the overall management of the F-111 System Program Office at the Aeronautical Systems Division, Wright-Patterson AFB, Ohio. The test aircraft used for the systems test program were FB-111A No. 1, USAF S/N 67-159; FB-111A No. 3, USAF S/N 67-161; FB-111A No. 44, USAF S/N 67-162; FB-111A No. 6, USAF S/N 67-7192; and FB-111A No. 27, USAF S/N 68-255.

This report presents the final results from the Category II reliability and maintainability evaluation. This evaluation used the data from the entire Category II test program which consisted of 1,308 flying hours accumulated during 504 missions (including 27 ground aborts).

Results of the FB-111A Category II test program have been or will be published in a series of reports. The titles for those reports are listed in references 1 through 11. A summary report (reference 12) containing an overall evaluation of the FB-111A aircraft will be published at the completion of the program.

PROGRAM OBJECTIVES

The primary objective of the FB-111A Category II systems evaluation was to insure that an operationally ready FB-111A system would be integrated into the SAC inventory in a minimum of time. The specific objectives of the Category II test program in accordance with AFR 80-14 and the FB-111A System Package Program were to:

1. Provide input data for determination of compliance with contract specifications for maintainability and reliability.

2. Obtain necessary data from flight test results to complete the Flight Manual (reference 11).

3. Evaluate design changes as required before incorporation into the system.

4. Demonstrate in as realistic and complete an environment as practicable that the complete system was functionally operative, operationally effective, and compatible with the other systems and supporting equipment required for operational use.

5. Determine whether the system was capable of and suitable for meeting the contract requirements and design objectives.

6. Provide equipment familiarization, experience, and maximum possible training for SAC and ATC within the limitations of the test program.

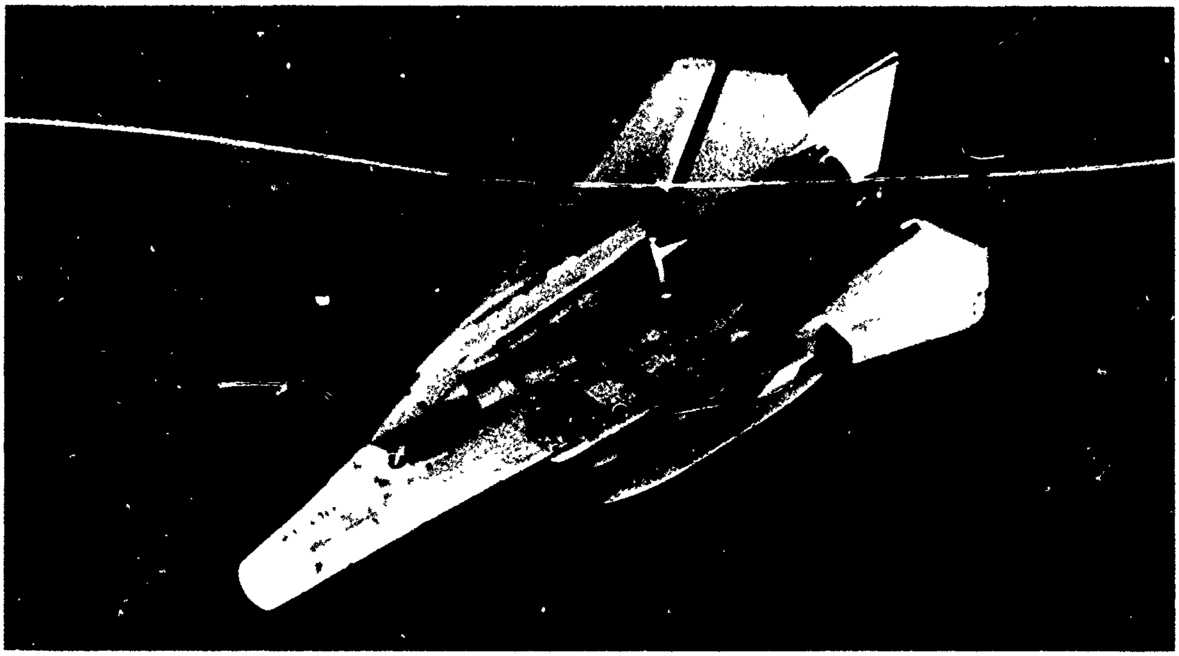
7. Demonstrate in the most realistic environment practicable that the complete system was maintainable with minimum resource outlay.

8. Determine the qualitative adequacy of the aerospace ground equipment (AGE).

9. Verify and evaluate the personnel subsystem.

AIRCRAFT DESCRIPTION

The FB-111A is a two-place (side-by-side) long-range fighter-bomber built by General Dynamics, Fort Worth Division. The aircraft was designed for all-weather supersonic operation at both low and high altitude. Mission capabilities include long range attack missions utilizing conventional or nuclear weapons. An automatic low altitude terrain following system enhances penetration capability. Power is provided by two TF-30 axial-flow, dual-compressor turbofan engines equipped with afterburners. The wings, equipped with leading edge slats and trailing edge flaps, may be varied in sweep, area, and aspect ratio by the selection of any wing sweep angle between 16 and 72.5 degrees. A selective forward wing sweep provides takeoff and landing capabilities at minimum speeds. For all other regimes, the wings are manually swept in accordance with desired Mach number. This feature provides the aircraft with a highly versatile operating envelope. The empennage consists of a fixed vertical stabilizer with rudder for directional control and a horizontal stabilizer that is moved symmetrically for pitch control and asymmetrically for roll control. The stability augmentation system incorporates triple redundant features which enhance system reliability. The tricycle-type forward retracting landing gear is hydraulically operated. The main landing gear consists of a single common trunnion upon which two wheels are singly mounted and contains only one extending/retracting/locking system, which ensures symmetrical main gear operation. Also, ground loads imposed upon the gear tend to extend the drag strut to the locked position. Stores are carried in a fuselage-enclosed weapons bay and externally on both pivoting and fixed wing-mounted pylons. The fuel system incorporates both inflight and single-point ground refueling capabilities.



TEST AND EVALUATION

GENERAL

This section contains a qualitative and quantitative analysis of the reliability and maintainability of each subsystem in the FB-111A aircraft as determined during the Category II test program. These results are presented by individual subsystem and for the overall aircraft. Evaluations that did not involve a specific subsystem are discussed at the conclusion of this section.

The quantitative analysis describes how each individual subsystem compared to the contractor's R&M predictions. Various R&M statistics are presented and analyzed as to the significant reasons for differences between the contractor's predictions and the measured Category II test results. Additional R&M statistics are presented for those users requiring further analysis. Insufficient failure and maintenance data were obtained on the aerospace ground equipment (AGE) to quantitatively evaluate it.

During the Category II test period, the monthly flying hours obtained varied from zero to a high of 76 hours per month. Because of this extreme variation, two R&M statistics most sensitive to a varying utilization rate, hardware mean time between failures (MTBF) and MMH/FH, were calculated using the six months data which corresponded with most flying hours (15 November 1970 through 15 May 1971 - 392 flying hours). All other R&M statistics were calculated using data from the entire Category II test program.

DATA COLLECTION

The Systems Effectiveness Data System (SEDS) was used for the reliability and maintainability analysis conducted on all aircraft subsystems during the Category II test program. Operational maintenance data were recorded on three different forms by maintenance and system engineering personnel. The data were input to two master history files, an operational data file, and a maintenance data file. The formatted file system (FFS) was used as an integral part of SEDS for the storage and retrieval of the data. The SEDS included the numerous computerized programs used to analyze this data. A detailed discussion of the forms used for data gathering (AFSC Form 258 and AFFTC Form 0-294) is contained in appendix I.

PROCEDURES AND GROUND RULES

Functional (Mission) Reliability

A functional or mission reliability analysis was performed on all aircraft subsystems. The flight hours obtained from the aircraft debriefing records were taken as the total flight time of all missions during which the particular subsystem was used with no credit being given for any ground operating or equipment checkout time. A maximum of 1,308 flying hours were accumulated during the 504 mission (including 28 ground aborts) covered in this analysis. Many of the subsystems had less operating time (appendix I) than the total aircraft, thus limiting

confidence in this data. Only aircrew-discovered discrepancies were recorded on the Aircraft Debriefing form, figure 1. Aircrew write-ups that reflected known design deficiencies for which corrective action had previously been initiated were deleted from these data. When two or more components of the same subsystem failed during a given flight, only one failure was considered.

Three categories of functional discrepancies were used: aborts, function loss, and function degradation. An abort was a malfunction that resulted in the premature termination of the primary mission due to a critical subsystem failure or a safety of flight malfunction. A function loss could have been of the complete subsystem or just the loss of one required mode of the subsystem. A functional degradation was a maintenance malfunction or degraded operation of a subsystem that functioned, but required corrective maintenance action. These categories were cumulative in a computation of functional reliability statistics; that is, mean flight hours between function loss included both aborts and function losses but not function degradations.

The following mission reliability statistics (appendix I), and tables III through XXXI, were calculated using the formulae in appendix II:

1. Mean Flying Hours Between Function Degradations (MFHBFD)

2. Mean Flying Hours Between Function Losses (MFHBFL)

3. Mean Flying Hours Between Aborts (MFHBA)

In addition, the statistically derived 90-percent lower confidence limits (LCL's) for the means were calculated. A 90-percent LCL (for a given parameter) is that value which the true value equals or exceeds for a given sample size with 90-percent probability. Thus, the proximity of the 90-percent LCL to the measured mean gives an indication of the certainty that should be attached to the measured mean. In other words, the closer the measured value is to the 90-percent LCL, the more certain it is that the measured value is the true value. The large difference between some of the measured probabilities and the associated LCL's was the result of low utilization rates and/or number of failures of some subsystems, which yielded less certainty in the measured results. The formulae and methods used in calculation of these statistics are presented in appendix II.

Appendix I contains the following statistics computed to show the probability that a system will be usable on any mission regardless of duration:

1. Probability of no functional degradation (P_{nd})

2. Probability of no functional loss (P_{nl})

3. Probability of no abort (P_{na})

In addition, the associated LCL's are also presented. Formulae used are contained in appendix II.

Hardware Reliability

A hardware reliability analysis was performed on all aircraft subsystems. The flight hours for the aircraft were multiplied by the operating time to flight time ratios ("use factors") shown in table I so that each subsystem could be credited with ground operating and checkout time. The "use factors" shown in table I were derived using the Operating Time Report for Selected Items (AFTO Form 4) as explained in appendix II. All confirmed failures were included (both air and ground crew discovered). A failure was considered confirmed if the corrective maintenance action verified that a component required repair. For example, if a component replaced on the aircraft subsequently bench-checked satisfactorily, no failure was assessed.

Results of the hardware reliability analysis are presented in tables III through XXXI.

Table I

SYSTEM OPERATING TIME VERSUS FLIGHT TIME RATIO (USE FACTOR)

Subsystem	Work Unit Code	Use Factor
Airframe	11000	1.0
Landing Gear	13000	1.3
Flight Controls	14000	1.3
Escape Capsule	16000	1.0
Engine	23000	1.3
Air Conditioning	41000	1.2
Electrical Power	42000	1.8
Lighting	44000	1.8
Hydraulic Power	45000	1.3
Fuel	46000	1.3
Oxygen	47000	1.0
Miscellaneous Utilities	49000	1.8
Instruments	51000	1.5
Autopilot	52000	1.5
HF Communications	61000	0.5
UHF Communications	63000	1.3
Interphone	64000	1.3
IFF	65000	1.3
Radio Navigation	71000	1.3
Bombing Navigation	73000	1.5
Fire Control	74000	0.9
Weapons Delivery	75000	0.5
Electronic Countermeasures	76000	1.0

Maintainability

A maintainability analysis was performed on aircraft subsystems using data obtained from the maintainability master history file. The maintenance manhour per flying hour (MMH/FH) values were computed by retrieving the total maintenance manhours for each two digit WUC and dividing this value by the total flying hours for the same period. The MMH/FH computations were separated into line and shop maintenance actions, that is, organizational and field level maintenance. Support general maintenance actions were considered separately from non-support general maintenance. All maintenance actions except for special instrumentation were considered in these calculations, not just those maintenance actions that related to the aircrew-discovered discrepancies. These statistics are presented in tables III through XXXI (along with contractor predicted values from reference 16) and summarized in table XXXII.

The MMH/FH values are nonparametric statistics. By considering each maintenance event as a separate data point it was possible to calculate a distribution of maintenance events (DOME). These data points for each subsystem were statistically tested by the Kolomogorov-Smirnov (K-S) goodness-of-fit test to determine whether they fit an exponential, Weibull, or log normal distribution. This computerized program computed the probability of the data points fitting each of these distributions as well as the K-S "D" statistic which defined whether or not the data points represented the specific distribution tested. The parametric distribution parameters for each distribution tested and the nonparametric statistics of the mean, variance, median (50th percentile) and M_{MAX} (90th percentile) were also computed (tables III through XXXI). All DOME statistics were tested for the line active hours, shop active hours, total active hours, line manhours, shop manhours, and total manhours. Many of these statistics were not determined because they did not fit any distribution tested or lacked adequate sample size. Active hours are the clockhours during which maintenance actions were actually being performed; that is, administrative and logistic delays were eliminated. Manhours were the active hours times the maintenance crew size. Mathematical formulations of the exponential, Weibull, and log normal distributions are contained in appendix II.

SUBSYSTEMS ANALYSIS BY WORK UNIT CODE

The following analyses by WUC compare the Category II test results with the contractor-predicted R&M figures of merit. A sample WUC listing is shown in table II. An explanation appears in appendix II.

Airframe (WUC 11000)

Reliability.

The relatively low hardware MTBF shown in table III was caused by minor component failures which were discovered between flights. As a result, the mission reliability (MFHBFL) shown in table III was good. The single repetitive failure mode consisted of 11 instances of wing tip cracks in 896 flying hours. After the incorporation of TCTO 1F111-B-A-578, which changed the wing tip structure, 396 flying hours were accumulated with no failures.

Table II
SAMPLE WUC LISTING

WORK UNIT CODE	
73000	BOMB NAVIGATION
73C00	ALTIMETER SET AN/APN-167
73CA0	RECEIVER/TRANSMITTER UNIT RT-771
73CAA	Receiver Assy
73CAB	Transmitter Assy
73CAC	Tracker Assy
73CAD	Power Supply
73CAE	Chassis Assy
73CAF	Amplifier, IF
73CAG	Cover, Electrical
73CA9	NOC
73CB0	ANTENNA, RECEIVER
73CB9	NOC
73CC0	ANTENNA, TRANSMITTER
73CC9	NOC
73CD0	RACK ELECTRICAL DISTRIBUTION MT-3403
73CDA	Rack, Plenum Chamber
73CDB	Distribution Box Assy
73CD9	NOC
73CE0	SWITCH COAX
73CE9	NOC
73CF0	INDICATOR, RADAR ALTIMETER
73CF9	NOC
73H00	INERTIAL NAVIGATION SYSTEM TYPE MARK II B
73HA0*	INERTIAL REFERENCE UNIT (Group 1)
73HAA	Instrument, Parameter Memory
73HAB	Module, Network Power Control
73HAC	Module, Network, Logic and Timing
73HAD	Module, Network, Memory/Sense
73HAE	Wiring, Harness Assy
73HAF	Module, Roll and Pitch Servo
73HAG	Stabilization Platform
73HAH	Gyro Displacement
73HAJ	Velocity, Meter
73HAK	Power Supply
73HAL	Controller, Gyro Speed
73HAM	Regulator, Band Pass Filter/Shift

Maintainability.

The MMH/FH measured in Category II testing was lower than contractor predictions. Table III shows the average clock time for a maintenance task on the airframe as 4.0 hours and 90 percent of all actions were completed in less than 8.3 hours. The wing tip replacement task required 1.5 clockhours and 3.0 manhours. The largest single maintenance task involved repair of plastic delamination under panel 3328 which required 140 clockhours and 250 manhours. Shop (intermediate level) clockhours and manhours were Weibull distributed.

TABLE III

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
AIRFRAME – WUC 11000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	21.7

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
59.5	327.0	1308.1
90% LCL	90% LCL	90% LCL
44.6	163.6	654.1

Probability of no

DEGRADATION	LOSS	ABORT
.96	.99	1.00
90% LCL	90% LCL	90% LCL
.94	.99	.99

Operating Hours/Flying Hours Ratio

1.0

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	3.1	0.4	3.5
Category II Results	2.7	0.1	2.8

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	326
Shop Active Hours	W	1.29,0.08	21
Total Active Hours	**	**	331
Line Man-Hours	**	**	326
Shop Active Hours	W	1.01,0.06	21
Total Man-Hours	**	**	331

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	4.0	37.6	2.0	8.3
Shop Man-Hours	6.3	23.9	5.0	12.8
Total Active Hours	4.3	42.6	2.0	8.8
Line Man-Hours	9.2	297.8	4.0	24.0
Shop Man-Hours	11.5	128.7	8.0	17.0
Total Man-Hours	9.8	308.9	4.0	24.0

LN – Log Normal
W – Weibull
EXP – Exponential

Landing Gear (WUC 13000)

Reliability.

The hardware reliability of the landing gear was low when all failures were considered although the measured mission reliability (MFHBFL) was good (table IV). This was caused by a large number of minor component failures which were detected between flights. Of the two aborts charged to this subsystem, one occurred when a cut nose tire was discovered during aircrew walk-around. The other abort was caused by an "unsafe" light in the gear handle after engine start. This was corrected by resetting the emergency shuttle valve.

The main landing gear tires averaged 25 landings per tire while the nose tire required replacement after an average of 23 landings. The only other repetitive failure mode was leaking brakes. There were 8 brakes changed for leaks during a time period covering 645 landings.

Maintainability.

The line (organizational level) MMH/FH for this subsystem was higher than the contractor-predicted value while the shop (field level) MMH/FH met predictions (table IV). This was caused by the low hardware reliability which required line corrective maintenance. The most frequent maintenance task was removal and replacement of wheel and tire assemblies which required 0.3 clockhours and 0.6 maintenance manhours (MMH) for a nose wheel or 1.5 clockhours and 3.0 MMH for a main wheel. A brake change required 2.0 clockhours and 6.0 MMH. The nonparametric DOME statistics (table IV) show that the task times for this subsystem are quite reasonable.

TABLE IV
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
LANDING GEAR – WUC 13000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	21.2

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
100.6	327.0	1308.1
90% LCL	90% LCL	90% LCL
69.0	163.6	245.8

Probability of no

DEGRADATION	LOSS	ABORT
.97	.99	1.00
90% LCL	90% LCL	90% LCL
.96	.99	1.00

Operating Hours/Flying Hours Ratio

1.3

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.1	0.1	0.2
Category II Results	1.3	0.1	1.4

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	147
Shop Active Hours	**	**	59
Total Active Hours	LN	0.78,0.85	165
Line Man-Hours	LN	1.45,1.34	147
Shop Active Hours	W	1.29,0.08	59
Total Man-Hours	EXP	0.10	165

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.3	6.3	1.5	5.1
Shop Man-Hours	3.2	6.5	2.0	5.8
Total Active Hours	3.2	9.3	2.2	6.8
Line Man-Hours	8.3	235.4	5.0	15.5
Shop Man-Hours	6.9	29.0	5.0	11.3
Total Man-Hours	9.9	226.5	6.0	22.5

LN – Log Normal
W – Weibull
EXP – Exponential

Flight Controls (WUC 14000)

Reliability.

The flight controls subsystem demonstrated the lowest hardware reliability of any non-avionic subsystem (table V). The No. 5 flap/vane components presented the major problem. Originally, these failures were considered to be caused by the uneven airflow around the wing tip cameras installed on some Category II test aircraft. When aircraft without cameras experienced similar failures, it was apparent cameras were not causing, but rather accelerating the failures. Engineering Change Proposals (ECP's) 2263 and 2846 (TCTO's 1F111-B-A-902 and 1F111-B-A-618, respectively) were designed to correct the problems with No. 5 flap. Seventy flight hours were accumulated after these changes were incorporated on one aircraft (FB-111A No. 3). During that period, the only failures were a bent No. 5 van and a worn No. 5 air deflector door hinge. Discounting failures in the No. 5 flap/vane area increases the hardware MTBF to approximately 26 hours. This more reasonable figure will be obtained only if ECP's 2263 and 4863 are effective.

The low hardware reliability seriously affected mission reliability (MFHBFL, table V). The aircrew "squawked" the flight controls an average of once every 25 flight hours. There were eight aborts for flight controls problems. Of these aborts, 5 were caused by the No. 5 flap/vane components.

Maintainability.

The measured line (organizational level) MMH/FH (table V) was over three times greater than the contractor predictions. However, 0.7 MMH/FH were expended on the No. 5 flap/vane area and an additional 1.4 MMH/FH were required for TCTO accomplishment. An additional 0.1 MMH/FH were required for shop (field level) accomplishment of TCTO's. After discounting the No. 5 flap/vane and TCTO manhours, the total measured MMH/FH of 1.7 compares favorably with the predicted 1.6 MMH/FH. The line, shop, and total manhour statistics were found to be log-normally distributed while the shop clock hours were exponentially distributed.

Escape Capsule Crew Module (WUC 16000)

Reliability.

The reliability of this subsystem (table VI) was acceptable when all discrepancies were considered. There were four aircrew-discovered discrepancies; all of which were function degradations. The four function degradations were: flash curtain rollers missing, right seat inoperative, right seat would not raise or lower, and left canopy handle lock tab would not lock. There were numerous hardware failures discovered between flights or during phase inspections by the ground crews. The failures were random among the components with no particular item having a high failure rate.

Maintainability.

The MMH/FH of this subsystem was very high in comparison with contractor-prediction (table VI). The primary cause was that the majority of the manhours was expended on removal and replacement of time change items, windshields, and crew seats to facilitate other maintenance.

One windshield which was replaced because of delamination. The DOME for line active and line manhours were tested and both found to be Weibull distributed.

TABLE V
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
FLIGHT CONTROLS – WUC 14000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	12.8

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
26.2	50.3	130.8
90% LCL	90% LCL	90% LCL
21.7	38.7	84.9

Probability of no

DEGRADATION	LOSS	ABORT
.90	.95	.98
90% LCL	90% LCL	90% LCL
.88	.93	.97

Operating Hours/Flying Hours Ratio

1.3

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	1.2	0.4	1.6
Category II Results	3.7	0.3	4.0

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	263
Shop Active Hours	EXP	0.28	33
Total Active Hours	**	**	268
Line Man-Hours	LN	1.86, 1.76	263
Shop Active Hours	LN	1.20, 1.51	33
Total Man-Hours	LN	1.90, 1.77	268

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	4.5	49.4	2.5	9.3
Shop Man-Hours	3.5	13.2	2.0	8.8
Total Active Hours	4.9	52.2	3.0	10.3
Line Man-Hours	15.9	1404.5	7.0	37.3
Shop Man-Hours	6.8	78.0	4.0	18.0
Total Man-Hours	16.4	1404.2	7.5	37.5

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE VI

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

ESCAPE CAPSULE – WUC 16000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	65.3

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.2	0.0	0.2
Category II Results	1.2	0.0	1.2

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
325.9	**	**
90% LCL	90% LCL	90% LCL
163.1	566.2	566.2

Probability of no

DEGRADATION	LOSS	ABORT
.99	1.00	1.00
90% LCL	90% LCL	90% LCL
.98	1.00	1.00

Operating Hours/Flying Hours Ratio

1.0

* NO PREDICTION

** STATISTIC NOT KNOWN

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	W	1.00,0.28	105
Shop Active Hours	W	0.64,0.88	7
Total Active Hours	W	1.00,0.28	107
Line Man-Hours	W	0.66,0.26	105
Shop Active Hours	W	0.54,0.78	7
Total Man-Hours	W	0.66,0.26	107

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	3.6	12.7	2.0	7.8
Shop Man-Hours	1.7	7.7	0.5	4.5
Total Active Hours	3.6	13.0	2.0	7.8
Line Man-Hours	10.3	257.8	4.0	20.7
Shop Man-Hours	2.7	30.2	0.5	8.1
Total Man-Hours	10.3	254.3	4.0	20.7

LN – Log Normal

W – Weibull

EXP – Exponential

Propulsion (WUC 23000)

Reliability.

The hardware reliability for the propulsion subsystem (table VII) was quite reasonable. It should be noted that the 21.7-hour MTBF is for the propulsion subsystem (i.e., two engines) as are the mission reliability statistics. The majority of the maintenance required was for repair of engine instruments and most aircrew writeups were on the same components. Of the eight aborts charged to the subsystem, two were caused by the spike controls on FB-111A No. 1 and two were caused by a high turbine inlet temperature on start which required a new indicator in one case and could not be duplicated in the other instance. The other aborts were caused by a failed N_1 tach generator which caused an overspeed light, a failed fuel control which prevented afterburner operation, a failed air ejector valve which caused an oil hot light, and one instance of severe stalls which could not be duplicated.

Maintainability.

The propulsion subsystem MMH/FH (table VII) was consistently better than the contractor predicted. This was attributed to reasonable reliability and a good maintainability design. Engine removal required 2.0 clockhours and 6.0 manhours while reinstallation required 4.0 clockhours and 12.0 manhours. Clock and manhours for line and shop were log-normally distributed.

Air Conditioning, Pressurization and Surface Ice Control (WUC 41000)

Reliability.

The reliability of this subsystem was low when all discrepancies were considered (table VIII). There were 27 aircrew-discovered discrepancies, 25 function degradations, and two function losses. The 25 function degradations were: seven environmental control system (ECS) failures which caused the forward equipment hot light to illuminate, eight failures in the pressurization system, seven failures in the air-conditioning system, one failure in the anti-icing systems and two intermittent FCS discrepancies. There were a large number of minor component failures which were detected between flights and during phase inspections. These minor failures lowered the reliability of the subsystem even further.

Maintainability.

The line (organizational level) MMH/FH for this subsystem more than doubled the contractor-predicted value while the shop (field level) MMH/FH was lower than contractor predictions (table VIII). This was caused by the low hardware reliability which required line corrective maintenance. The most frequent tasks were the removal and replacement of components in the ECS and pressurization system. The nonparametric DOME statistics (table VIII) for line active and shop manhours were tested and found to be exponential and Weibull distributed, respectively. The values for these statistics were quite reasonable.

TABLE VII

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

TURBOJET POWER PLANT – 23000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	28.2

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
25.2	130.8	163.5
90% LCL	90% LCL	90% LCL
20.9	84.9	100.7

Probability of no

DEGRADATION	LOSS	ABORT
.90	.98	.98
90% LCL	90% LCL	90% LCL
.88	.97	.98

Operating Hours/Flying Hours Ratio

1.3

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	2.4	1.1	3.5
Category II Results	0.9	0.3	1.2

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.89,1.08	186
Shop Active Hours	LN	1,85,2.46	58
Total Active Hours	**	**	218
Line Man-Hours	LN	1.64,2.05	186
Shop Active Hours	LN	2.62,4.12	58
Total Man-Hours	**	**	218

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	4.1	25.5	2.5	9.2
Shop Man-Hours	17.5	602.8	5.3	50.5
Total Active Hours	8.2	228.8	3.0	23.0
Line Man-Hours	15.0	900.4	4.0	42.7
Shop Man-Hours	63.0	9031.5	8.1	198.8
Total Man-Hours	29.5	3758.8	5.6	91.7

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE VIII

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
AIR CONDITIONING AND PRESSURIZATION – WUC 41000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	29.4

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
49.8	647.9	**
90% LCL	90% LCL	90% LCL
48.3	243.5	562.8

Probability of no

DEGRADATION	LOSS	ABORT
.95	1.00	1.00
90% LCL	90% LCL	90% LCL
.93	.99	1.00

Operating Hours/Flying Hours Ratio

1.2

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.3	0.2	0.5
Category II Results	0.7	0.0	0.7

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	EXP	0.26	100
Shop Active Hours	LN	-0.12,1.09	11
Total Active Hours	EXP	0.25	102
Line Man-hours	LN	1.32,1.41	100
Shop Active Hours	W	1.03,0.60	11
Total Man-Hours	LN	1.33,1.41	102

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	3.9	41.8	2.2	7.8
Shop Man-Hours	1.4	1.7	1.0	2.7
Total Active Hours	3.9	41.3	2.5	7.9
Line Man-Hours	8.0	295.2	4.0	15.8
Shop Man-Hours	1.6	2.5	1.0	3.7
Total Man-Hours	8.0	289.7	4.0	15.8

LN – Log Normal
W – Weibull
EXP – Exponential

Electrical Power Supply (WUC 42000)

Reliability.

The reliability of this subsystem was acceptable (table IX). There were only four aircrew-discovered discrepancies; three function degradations, and one mission abort. The three function degradations were: two generator power contactor failures, and three circuit breakers popped. On one flight the generator power contactor caused electrical transients when the engine was shutdown, and the other generator power contactor caused the inertial navigation system (INS) to dump when transferring from ground power. There were several hardware failures that were discovered between flights while performing maintenance on other components: two generator failures, four external power monitor failures, and one generator power contactor failure. The four external power monitor failures prevented application of external power to the aircraft. One generator failure caused a ground abort after being overserviced by maintenance and was not used in the analysis of the data.

Maintainability.

The MMH/FH for this subsystem was 0.1, about equal to contractor predictions. Most of the maintenance was for removing and replacing external power monitors which required on an average of 4.0 MMH per failure and making battery inspections, which required 2.0 MMH per inspection. The DOME for line active and line manhours were tested and both found to be log-normally distributed (table IX).

Lighting System (WUC 44000)

Reliability.

The reliability of this system was considered acceptable (table X). There were 14 aircrew-discovered discrepancies, 10 function degradations, and 4 function losses. The 10 degradations were primarily burnt bulbs or illuminated warning lights. The four losses were: three rotating beacons failures, and both green lights in gear down indicator burned out.

There were numerous hardware failures discovered by the ground crews during preflight and postflight inspections. There were seven rotating beacon failures, five master caution light failures and two flasher failures which were discovered by the ground crew.

Maintainability.

The MMH/FH for the subsystem was 0.1 which was equal to the contractor predictions (table X). Most of the maintenance manhours were spent replacing burned out bulbs which required an average of 0.5 MMH per failure while removal and replacement of rotating beacon assemblies and master caution panels required an average of 1.0 and 2.0 MMH per failure, respectively. The DOME for line active and line manhours were tested and found to be log-normal and exponentially distributed (table X).

TABLE IX

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

ELECTRICAL POWER SUPPLY – WUC 42000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	235.0

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
327.0	1308.1	1308.1
90% LCL	90% LCL	90% LCL
163.6	336.3	336.3

Probability of no

DEGRADATION	LOSS	ABORT
.99	1.00	1.00
90% LCL	90% LCL	90% LCL
.99	.99	.99

Operating Hours/Flying Hours Ratio

1.8

* NO PREDICTION

** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.1	0.1	0.2
Category II Results	0.1	0.0	0.1

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	W	1.19,0.37	43
Shop Active Hours	**	**	0
Total Active Hours	LN	0.61,0.83	45
Line Man-Hours	LN	1.00,0.85	43
Shop Active Hours	**	**	0
Total Man-Hours	LN	1.13,1.32	45

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.2	3.3	1.7	4.2
Shop Man-Hours	**	**	**	**
Total Acti~e Hours	3.8	111.5	1.7	4.9
Line Man-Hours	4.3	31.6	2.0	8.8
Shop Man-Hours	**	**	**	**
Total Man-Hours	10.1	1442.7	2.0	11.3

LN – Log Normal

W – Weibull

EXP – Exponential

TABLE X
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
LIGHTING SYSTEM – WUC 44000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	107.5

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
81.8	436.0	**
90% LCL	90% LCL	90% LCL
58.3	195.8	568.1

Probability of no

DEGRADATION	LOSS	ABORT
.97	.99	1.00
90% LCL	90% LCL	90% LCL
.96	.99	1.00

Operating Hours/Flying Hours Ratio

1.8

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.1	0.01	0.1
Category II Results	0.1	0.0	0.1

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.00,0.40	38
Shop Active Hours	EXP	0.38	6
Total Active Hours	LN	0.15,0.59	38
Line Man-Hours	EXP	0.39	38
Shop Active Hours	EXP	0.27	6
Total Man-Hours	LN	0.66,0.81	38

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	1.2	0.7	1.0	2.3
Shop Man-Hours	2.2	1.3	2.5	3.3
Total Active Hours	1.6	2.1	1.0	3.3
Line Man-Hours	2.5	7.6	2.0	4.5
Shop Man-Hours	3.2	5.9	2.6	6.0
Total Man-Hours	3.0	13.6	2.0	6.1

LN – Log Normal
W – Weibull
EXP – Exponential

Pneudraulic Power Supply (WUC 45000)

Reliability.

The reliability of this subsystem was somewhat low when all discrepancies were considered (table XI). There were seven aircrew-discovered discrepancies, four function degradations, one function loss, and two mission aborts. The four function degradations were: three primary hydraulic pressure switches inoperative, and one hydraulic pressure transmitter caused indicator to read 3,300 psi with engines running and 200 psi with engine shutdown. One function loss was attributed to right engine primary hydraulic pump light illuminating. The two mission aborts were: complete loss of utility hydraulic system when a hydraulic expansion swivel joint broke and the other was when the utility hydraulic light came on in flight. There were numerous hardware failures discovered between flights or in phase inspections. The failures were random among the components in the hydraulic system with no particular component having a high failure rate.

Maintainability.

The MMH/FH for this system was below contractor-predicted values (table XI). The majority of the manhours were for removal and replacement of leaky parts throughout the system. The DOME for line active and line manhours were tested and found to be exponentially and Weibull distributed, respectively (table XI).

Fuel System (WUC 46000)

Reliability.

The hardware reliability of the fuel system was acceptable (table XII). There were 29 aircrew-discovered function degradations and 1 mission abort. In the function degradations there were: 7 failures in the distribution system, which caused the fuel distribution light to illuminate; 6 failures in the inflight-refueling system; 4 failures in the fuel quantity indication system; 11 failures in the fuel transfer system; and 1 failure in the fuel dump system.

In the fuel distribution system there were varying component failures that caused the distribution light to illuminate. All the problems related to the inflight refueling system involved making contact with the tanker. The fuel quantity tanker system had one bad indicator and the other failures involved calibration problems. This system also caused the only abort against the fuel system. The fuel transfer system had three transfer pump failures and random failures among switches and valves. Fuel dumped overboard on one instance when an engine was started. Retorquing a loose Wiggins coupling corrected the discrepancy. There were a large number of fuel leaks detected between flights and corrected by the ground crew.

Maintainability.

The line (organizational level) MMH/FH for the fuel system was slightly higher than the contractor-predicted value while the shop (field level) MMH/FH met predictions (table XII). The largest consumer of MMH in the fuel system was repairing fuel cell leaks and trouble-

shooting fuel system problems. The average manhours required in repairing fuel cell leaks was 42.5 with one task requiring 121.0 manhours. The line active, line manhour, and total manhour statistics were tested and found to be log-normally distributed.

TABLE XI

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

PNEUDRAULIC POWER SUPPLY – WUC 45000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	63.7

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
163.5	327.0	436.0
90% LCL	90% LCL	90% LCL
1(0.7	163.6	195.8

Probability of no

DEGRADATION	LOSS	ABORT
.98	.99	.99
90% LCL	90% LCL	90% LCL
.98	.99	.99

Operating Hours/Flying Hours Ratio

1.3

* NO PREDICTION

** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.4	0.2	0.6
Category II Results	0.4	0.0	0.4

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	EXP	0.36	44
Shop Active Hours	**	**	0
Total Active Hours	EXP	0.36	44
Line Man-Hours	W	0.74,0.28	44
Shop Active Hours	**	**	0
Total Man-Hours	W	0.74,0.28	44

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.7	8.5	1.5	7.6
Shop Man-Hours	**	**	**	**
Total Active Hours	2.7	8.5	1.5	7.6
Line Man-Hours	7.0	92.8	3.5	20.5
Shop Man-Hours	**	**	**	**
Total Man-Hours	7.0	92.8	3.5	20.5

LN – Log Normal

W – Weibull

EXP – Exponential

TABLE XII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
FUEL SYSTEM – WUC 46000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	127.5

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
54.3	1302.4	1302.4
90% LCL	90% LCL	90% LCL
41.2	344.8	344.8

Probability of no

DEGRADATION	LOSS	ABORT
.95	1.00	1.00
90% LCL	90% LCL	90% LCL
.94	.99	.99

Operating Hours/Flying Hours Ratio

1.3

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.3	0.0	0.3
Category II Results	0.4	0.0	0.4

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	1.01,1.14	88
Shop Active Hours	LN	0.39,0.77	10
Total Active Hours	LN	1.06,1.14	89
Line Man-Hours	LN	1.96,2.05	88
Shop Active Hours	W	0.54,0.49	10
Total Man-Hours	LN	2.01,2.05	89

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	4.5	23.1	3.0	8.5
Shop Man-Hours	2.2	6.0	1.3	4.0
Total Active Hours	4.7	24.4	3.0	8.8
Line Man-Hours	18.0	908.8	8.0	37.8
Shop Man-Hours	6.4	166.3	1.3	8.0
Total Man-Hours	18.6	917.7	9.0	41.0

LN – Log Normal
W – Weibull
EXP – Exponential

Oxygen System (WUC 47000)

Reliability.

The reliability of this system was considered acceptable (table XIII). There were two aircrew-discovered function degradations and numerous ground crew-discovered hardware failures. The function degradations were: right oxygen regulator inoperative, and the emergency oxygen regulator leaking. Some of the ground crew failures were: crimped oxygen hoses, leaking liquid oxygen converter, and several leaking valves and regulators.

Maintainability.

The MMH/FH for the oxygen system were equal to contractor-predicted values (table XIII). This did not include servicing which came under scheduled maintenance. The majority of manhours required were for time-change-items. The easy access (removal and replacement) of the liquid oxygen converter allowed it to be removed from the aircraft and taken to a liquid oxygen servicing cart for refilling while the aircraft was being fueled or having other maintenance performed. The DOME for both line active and line manhours were tested and found to be log-normally distributed (table XIII).

Miscellaneous Utilities (WUC 49000)

Reliability.

The reliability of this system was acceptable (table XIV). There were no aircrew-discovered discrepancies reported. There were six ground crew-discovered discrepancies, two fire detection control unit, and four sensing element failures. Repair involved removing and replacing the components. On the average, 2.0 MMH to change a control unit and 1.0 MMH to change a sensing element were required.

Maintainability.

The MMH/FH for this subsystem was below contractor-predicted values (table XIV). The majority of the manhours was expended replacing sensing elements in the fire detection system. The DOME for line active and line manhours was tested and found to be Weibull and exponentially-distributed, respectively (based on a very small sample size).

TABLE XIII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
OXYGEN SYSTEM – WUC 47000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	392.3

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
652.4	**	**
90% LCL	90% LCL	90% LCL
245.2	566.7	566.7

Probability of no

DEGRADATION	LOSS	ABORT
1.00	1.00	1.0U
90% LCL	90% LCL	90% LCL
.99	1.00	1.00

Operating Hours/Flying Hours Ratio

1.0

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.0	0.0	0.0
Category II Results	0.0	0.0	0.0

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.36,0.64	19
Shop Active Hours	**	**	0
Total Active Hours	LN	0.36,0.65	19
Line Man-Hours	LN	0.72,0.12	19
Shop Active Hours	**	**	0
Total Man-Hours	LN	0.73,1.22	19

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.0	5.4	1.2	3.8
Shop Man-Hours	**	**	**	**
Total Active Hours	2.1	5.4	1.2	4.0
Line Man-Hours	4.6	89.5	1.5	8.8
Shop Man-Hours	**	**	**	**
Total Man-Hours	4.7	89.4	1.5	8.8

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XIV

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

MISCELLANEOUS UTILITIES – WUC 49000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	705.0

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
**	**	**
90% LCL	90% LCL	90% LCL
566.8	566.8	566.8

Probability of no

DEGRADATION	LOSS	ABORT
1.00	1.00	1.00
90% LCL	90% LCL	90% LCL
1.00	1.00	1.00

Operating Hours/Flying Hours Ratio

1.8

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.2	0.0	0.2
Category II Results	0.0	0.0	0.0

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	W	1.27,0.44	8
Shop Active Hours	**	**	0
Total Active Hours	W	1.27,0.44	8
Line Man-Hours	EXP	0.19	8
Shop Active Hours	**	**	0
Total Man-Hours	EXP	0.19	8

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	1.8	1.9	1.5	3.7
Shop Man-Hours	**	**	**	**
Total Active Hours	1.8	1.9	1.5	3.7
Line Man-Hours	4.6	12.5	3.3	9.3
Shop Man-Hours	**	**	**	**
Total Man-Hours	4.6	12.5	3.3	9.3

LN – Log Normal
W – Weibull
EXP – Exponential

Instruments (WUC 51000)

Reliability.

The hardware MTBF shown in table XV resulted from scattered failures. No single component appeared to have a dominant failure mode. The instruments subsystem averaged one aircrew write-up every 18 flight hours. Of these write-ups, 35 percent were traced to problems with interfacing subsystems and 14 percent could not be duplicated. One abort was charged to the subsystem when a failed electronic control amplifier caused the primary altimeter to be inoperative.

Maintainability.

The MMH/FH required by the instrument subsystem was more than twice that predicted by the contractor (table XV). A contributing reason for this high statistic was the inability of the maintenance technician to isolate a failure to the correct line replaceable unit (LRU). In many instances, several LRU's had to be removed and bench-checked to determine which unit had failed. Of the total 1.8 MMH/FH measured, 0.3 MMH/FH were expended removing, bench-checking, and replacing good components. The remaining MMH/FH overage was attributed to low reliability.

Autopilot (WUC 52000)

Reliability.

The hardware reliability (table XVI) demonstrated by the autopilot subsystem was considered reasonable although the mission reliability was low. The majority of the aircrew-write-ups were considered functional degradations in that a loss or improper response of only one mode of autopilot was involved. Of the eight aborts charged to this subsystem, three were caused by the feel-trim assembly, and one each by the roll computer, roll rate gyro, and Central Air Data Computer. Six of the eight abort-causing failures were discovered during the pretaxi surface motion check.

Maintainability.

The measured MMH/FH (table XVI) exceeded predictions for the autopilot subsystem. Much of the maintenance was for intermittent or flight peculiar (that is, altitude-, temperature-, and g-related) discrepancies. A full 25 percent of the aircrew write-ups could not be duplicated and hence produced no positive corrective maintenance action. When a failure was duplicated there was difficulty isolating it to the correct LRU. A total of 0.4 MMH/FH was expended in removing, bench-checking, and replacing good units. Also, of the total MMH/FH shown in table XVI, 0.7 MMH/FH were due to TCTO accomplishment.

TABLE XV
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
INSTRUMENTS – WUC 51000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	42.0

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
17.8	129.7	1296.9
90% LCL	90% LCL	90% LCL
15.2	84.2	333.4

Probability of no

DEGRADATION	LOSS	ABORT
.85	.98	1.00
90% LCL	90% LCL	90% LCL
.83	.97	.99

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.7	0.1	0.8
Category II Results	0.9	0.9	1.8

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.95,0.73	106
Shop Active Hours	LN	1.49,0.83	65
Total Active Hours	LN	1.58,0.97	108
Line Man-Hours	LN	1.47,1.10	106
Shop Active Hours	EXP	0.06	65
Total Man-Hours	LN	2.24,1.41	108

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	3.7	14.4	2.1	8.0
Shop Man-Hours	6.5	34.3	4.5	14.4
Total Active Hours	7.6	57.3	4.5	16.0
Line Man-Hours	7.5	82.6	4.0	17.8
Shop Man-Hours	16.6	297.4	10.0	35.5
Total Man-Hours	17.3	395.0	10.4	41.3

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XVI

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

AUTOPILOT – WUC 5200

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	117.4

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
28.1	90.4	158.1
90% LCL	90% LCL	90% LCL
23.1	62.9	97.4

Probability of no

DEGRADATION	LOSS	ABORT
.97	.97	.98
90% LCL	90% LCL	90% LCL
.89	.96	,97

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.6	0.3	0.9
Category II Results	0.9	0.9	1.8

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.99,0.75	103
Shop Active Hours	W	1.05,0.09	56
Total Active Hours	LN	1.54,1.47	107
Line Man-Hours	LN	1.83,1.49	103
Shop Active Hours	EXP	0.04	56
Total Man-Hours	W	0.78,0.09	107

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	3.8	12.5	3.0	7.8
Shop Man-Hours	9.7	84.6	8.0	16.8
Total Active Hours	8.7	108.3	4.0	19.4
Line Man-Hours	12.4	259.2	6.0	31.8
Shop Man-Hours	25.4	654.9	19.8	47.6
Total Man-Hours	25.2	1066.2	14.9	59.5

LN – Log Normal
W – Weibull
EXP – Exponential

HF Communications (WUC 61000)

Reliability.

The reliability of the AN/ARC-123 HF Communications subsystem was very low. The Category II MTBF results were approximately one-tenth of the prediction (table XVII). There were 13 aircrew-discovered discrepancies, 6 function degradations, and 7 function losses. The six function degradations were: two control panel failures, two receiver-transmitter (R/T) unit failures, one amplifier and one coupler failure. The seven function losses were; four R/T unit failures, two failures which could not be duplicated, and one coupler failure.

Of the six R/T unit failures, two were reparable in the shop (field level) while the other four had to be sent to the depot for repair. The couplers and control panels were repaired locally except for one coupler and one control panel which were sent to the depot.

Maintainability.

The MMH/FH for this subsystem was double the predicted value (table XVII). The line (organizational level) maintenance was equal to the predictions, while the shop (field level) was three times greater than the predicted value (table XVII). The majority of the shop manhours was spent repairing or replacing modules in the R/T units. If module replacement did not solve the problem, the R/T units were sent to the depot for repair. The parametric statisitcs for all maintenance parameters were tested and found to be log-normally distributed.

UHF Communications (WUC 63000)

Reliability.

The relatively low hardware MTBF of the AN/ARC-109 communications subsystem shown in table XVIII was caused by numerous component failures. There were 44 aircrew-discovered discrepancies: 39 function degradations, 4 function losses, and 1 mission abort. The 39 function degradations were: 17 R/T unit failures, 1 UHF foot switch failure, 3 antenna coaxial switch failures, 5 antenna failures, and 13 write-ups that could not be duplicated. The four function losses were: three R/T unit failures and one antenna failure. The mission abort was a R/T unit failure.

There was a total of 21 R/T unit failures discovered by the aircrew. Of the 21 R/T unit hardware failures, five modules were replaced by the shop (field level). These modules were then sent to the depot for repair. The remaining 16 R/T unit failures required alignment and adjustments to modules within the R/T unit. After this was done, the R/T unit bench-checked as serviceable and returned to the aircraft.

Maintainability.

The MMH/FH for this subsystem was slightly lower than predictions (table XVIII). Even though the reliability of the hardware was low the time for repair was about equal to predictions. This was because most of the line MMH's were spent on removal and replacement of R/T units while troubleshooting discrepancies that could not be duplicated. The shop MMH's were slightly lower than predicted because most of the time

was spent in adjustment to the R/T units. Overall, the maintainability of this system was quite reasonable. The DOME parametric statistics for all maintenance statistics were tested and found to be log-normally distributed.

TABLE XVII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
HF COMMUNICATIONS – WUC 61000

HARDWARE RELIABILITY

Predicted MTBF	600.0
Category II Results	65.4

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
46.2	85.8	**
90% LCL	90% LCL	90% LCL
31.7	51.0	260.9

Probability of no

DEGRADATION	LOSS	ABORT
.93	.96	1.00
90% LCL	90% LCL	90% LCL
.90	.94	.99

Operating Hours/Flying Hours Ratio

0.5

* NO PREDICTION

** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.1	0.1	0.2
Category II Results	0.1	0.3	0.4

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.84,1.08	19
Shop Active Hours	LN	1.35,2.90	12
Total Active Hours	LN	1.47,1.93	20
Line Man-Hours	LN	1.48,1.59	19
Shop Active Hours	LN	2.09,4.19	12
Total Man-Hours	LN	2.20,2.71	20

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	4.2	42.1	2.0	7.3
Shop Man-Hours	11.5	264.8	5.0	26.1
Total Active Hours	10.9	304.8	4.1	18.6
Line Man-Hours	9.7	221.3	3.2	24.3
Shop Man-Hours	30.6	1744.3	14.0	54.9
Total Man-Hours	27.6	1778.7	9.0	54.2

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XVIII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
UHF COMMUNICATIONS – WUC 63000

HARDWARE RELIABILITY

Predicted MTBF	273.0
Category II Results	63.7

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
28.8	259.1	1295.7
90% LCL	90% LCL	90% LCL
23.6	139.7	333.1

Probability of no

DEGRADATION	LOSS	ABORT
.91	.99	1.00
90% LCL	90% LCL	90% LCL
.89	.98	1.00

Operating Hours/Flying Hours Ratio

1.3

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.2	0.2	0.4
Category II Results	0.2	0.1	0.3

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.35,0.47	76
Shop Active Hours	LN	1.27,1.18	38
Total Active Hours	LN	0.96,1.20	78
Line Man-Hours	LN	0.94,0.61	76
Shop Active Hours	LN	1.87,1.81	38
Total Man-Hours	LN	1.53,1.59	78

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	1.8	1.8	1.4	3.3
Shop Man-Hours	6.8	117.6	3.1	17.2
Total Active Hours	5.0	71.8	2.8	9.7
Line Man-Hours	3.4	6.9	2.7	7.1
Shop Man-Hours	14.5	506.3	6.1	41.3
Total Man-Hours	10.4	312.7	4.9	21.0

LN – Log Normal
W – Weibull
EXP – Exponential

Interphone System (WUC 64000)

Reliability.

The reliability of the AN/AIC-25 interphone system was well below predicted values (table XIX). There were 13 aircrew-discovered discrepancies: 12 of which were function degradations and 1 a function loss. The function degradations were: 1 control panel with no hot mic at altitude, 1 control panel not secured in the cockpit, and 10 intermittent transmission and reception failures. The navigator foot switch was inoperative in the only function loss.

Maintainability.

The MMH/FH for the interphone system amounted to 0.1, about equal to the contractor predictions. Most of the maintenance was for troubleshooting or repairing interphone cords associated with the intermittent transmission and reception failures. The DOME for line active and line manhours were tested and both found to be log-normally distributed (table XIX).

Identification Friend or Foe (WUC 65000)

Reliability.

The reliability of the AN/APX-64V IFF was below the predicted value (table XX). There were 11 aircrew-discovered discrepancies, 5 function degradations and 6 function losses. The five function degradations were: three intermittent operations of IFF and two intermittent caution lights. The six function losses were: one IFF antenna lost inflight and five R/T unit failures. All R/T units were repaired in the shop (field level) by replacing various modules in three R/T units and repairing connectors in the other two R/T units. One power supply module and one generator module were not reparable this station and were sent to the depot level for repair.

Maintainability.

The MMH/FH for this subsystem came to 0.1 which was about equal to predictions (table XX). The majority of the maintenance manhours was for troubleshooting intermittent discrepancies and for shop (field level) repair of the R/T units. The DOME for line active and shop active hour statistics were found to be Weibull distributed, while line and shop manhour statistics were found to be log-normally distributed.

TABLE XIX

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

INTERPHONE – WUC 64000

HARDWARE RELIABILITY

Predicted MTBF	1000
Category II Results	510.0

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
108.7	**	**
90% LCL	90% LCL	90% LCL
73.3	566.3	566.3

Probability of no

DEGRADATION	LOSS	ABORT
.98	1.00	1.00
90% LCL	90% LCL	90% LCL
.97	1.00	1.00

Operating Hours/Flying Hours Ratio

1.3

** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.0	0.0	0.0
Category II Results	0.0	0.0	0.1

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.06,0.31	21
Shop Active Hours	**	**	0
Total Active Hours	LN	0.01,0.57	21
Line Man-Hours	LN	0.37,0.49	21
Shop Active Hours	**	**	0
Total Man-Hours	LN	0.45,0.80	21

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	1.1	0.5	1.0	1.8
Shop Man-Hours	**	**	**	**
Total Active Hours	1.6	7.1	1.0	1.8
Line Man-Hours	1.8	1.4	1.3	3.5
Shop Man-Hours	**	**	**	**
Total Man-Hours	2.7	21.1	1.3	3.5

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XX
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
IFF/SIF – WUC 65000

HARDWARE RELIABILITY

Predicted MTBF	400
Category II Results	255

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
107.8	215.6	**
90% LCL	90% LCL	90% LCL
72.7	122.8	561.7

Probability of no

DEGRADATION	LOSS	ABORT
.98	.99	1.00
90% LCL	90% LCL	90% LCL
.96	.98	1.00

Operating Hours/Flying Hours Ratio

1.3

** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.1	0.1	0.2
Category II Results	0.0	0.1	0.1

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	W	4.08,0.01	8
Shop Active Hours	W	2.21,0.01	6
Total Active Hours	W	1.63,0.04	9
Line Man-Hours	LN	1.40,0.20	8
Shop Active Hours	LN	2.48,0.37	6
Total Man-Hours	EXP	0.07	9

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.8	0.5	2.8	3.5
Shop Man-Hours	6.9	10.3	6.6	10.4
Total Active Hours	7.0	19.2	6.8	13.4
Line Man-Hours	4.4	4.9	3.8	7.5
Shop Man-Hours	14.1	89.0	12.5	23.2
Total Man-Hours	13.3	139.8	10.2	30.7

LN – Log Normal
W – Weibull
EXP – Exponential

Radio Navigation (WUC 71000)

Reliability.

The reliability of the subsystem was about half of the predicted value (table XXI) for the tacan only. There were no instrument landing approach system (ILAS) failures during this data span so no MTBF value could be derived. The Category II MTBF result is for the tacan only.

There were 22 aircrew-discovered discrepancies, 17 discrepancies against the tacan system, and 5 discrepancies against the ILAS system.

Of the 17 tacan discrepancies, 12 were function degradations, and 5 were function losses. The 12 function degradation were: 9 R/T unit failures and 3 discrepancies that could not be duplicated. The five function losses were all R/T unit failures.

Repair of the R/T unit failures required the removal and replacement of modules within the R/T unit of all failures except one which bench-checked as satisfactory. There were four modules that had a high failure rate. These were: 10 bearing module failures, 6 range mechanical module failures, 4 RF modulator module failures and 3 power supply module failures. All the module failures were not repairable at the field level and were sent to depot for repair.

The five ILAS discrepancies were four function degradations and one function loss. The four function degradations could not be duplicated by the maintenance crew, while the one function loss was attributed to a broken antenna coaxial cable. The reliability of this subsystem could not be adequately evaluated from this data due to the low utilization rate of this subsystem.

Maintainability.

The MMH/FH of table XXI are for tacan subsystem only as there were no ILAS discrepancies during that time period. The line (organizational level) MMH/FH for this subsystem was slightly higher than the predicted value while the shop (field level) more than doubled the predicted value. This was caused by the low hardware reliability which required shop corrective maintenance. The shop repairs consumed the largest amount of manhours primarily after the removal and replacement of a module within the R/T unit required realignment of the R/T unit.

The total MMH/FH of the radio navigation subsystem more than doubled the predicted value (table XXI) primarily because of shop repairs. The line-active and shop-active DOME parametric statistics were tested and found to be log-normally and Weibull distributed, while line manhours and shop manhours were both found to be Weibull distributed.

TABLE XXI

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
RADIO NAVIGATION – WUC 71000

HARDWARE RELIABILITY

Predicted MTBF	227.0
Category II Results	125.6

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
75.1	255.4	**
90% LCL	90% LCL	90% LCL
54.1	137.1	554.7

Probability of no

DEGRADATION	LOSS	ABORT
.96	.99	1.00
90% LCL	90% LCL	90% LCL
.95	.98	1.00

Operating Hours/Flying Hours Ratio

1.3

** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.1	0.2	0.3
Category II Results	0.2	0.5	0.7

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	1.02,0.49	[illegible]
Shop Active Hours	W	1.52,0.02	15
Total Active Hours	W	1.20,0.05	24
Line Man-Hours	W	1.06,0.12	22
Shop Active Hours	W	1.28,0.01	15
Total Man-Hours	EXP	0.04	24

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	3.5	7.0	2.5	5.8
Shop Man-Hours	12.3	66.7	10.5	23.8
Total Active Hours	10.9	81.9	9.7	21.3
Line Man-Hours	4.3	18.4	2.5	7.3
Shop Man-Hours	30.9	587.2	22.8	70.4
Total Man-Hours	25.9	605.5	20.4	60.8

LN – Log Normal
W – Weibull
EXP – Exponential

Bombing Navigation (WUC 73000)

Reliability.

Both the mission and hardware reliability for the bombing navigation subsystem were considered low (table XXII). In subsequent analyses, the predicted MTBF's were qualification test statistics that applied to MIL-STD-781A testing (reference 17) and were obtained from a Program Reliability Review (reference 18). Some degradation in reliability must be expected between the environments specified in MIL-STD-781A and the actual flight environment, but these predicted MTBF's are used as a basis for comparison.

Maintainability.

The measured MMH/FH was over twice that predicted by the contractor (table XXII). This overage was attributed to both low reliability and low maintainability. The majority of the line MMH was required for troubleshooting. Once a faulty component was isolated, removal and replacement were easily accomplished. Further contributing to the problems of maintaining the subsystem was the difficulty in duplicating altitude-, temperature-, or g-related failures. Over the entire test program, 37 percent of the aircrew write-ups could not be duplicated, and a writeup that could not be duplicated invariably required more manhours than if a failure had been found.

It should be noted that aircrew debriefing was and will be a critical maintenance function for this subsystem. Subsystem functions were often written up by the aircrew as malfunctioning when in fact another subsystem function had failed and provided an inaccurate input to the subsystem function reported as failed.

Radar Altimeter Set (WUC 73C00)

Reliability.

The reliability of the AN/APN-167 radar altimeter was extremely low. The MTBF was far below the predicted value (table XXIII). There were 14 aircrew-discovered discrepancies, 13 function degradations, and one function loss. The 13 function degradations were: 4 indicator failures, 5 R/T unit failures and 4 discrepancies that could not be duplicated. The four indicator failures were not repairable in the shop (field level) and were sent to the depot for repair. The five R/T unit failures were required by alignment for two R/T units and by replacement of modules in the other three R/T units. The modules were then sent to the depot for repair. The one function loss was caused by an indicator failure which was sent to the depot for repair. The "could not duplicate" rate was 20 percent of all discrepancies for this subsystem.

Maintainability.

The Category II MMH/FH results for this subsystem are quite reasonable, but there are not predicted values for comparison (table XXIII). The line (organizational level) and shop (field level) MMH/FH values were the same.

The DOME parametric statistics for line active, line manhours, shop manhours were found to be log-normally distributed; while shop active,

total active and total manhours were found to be Weibull distributed (table XXIII).

TABLE XXII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
BOMBING NAVIGATION – WUC 73000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	21.2

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
5.5	14.8	118.8
90% LCL	90% LCL	90% LCL
4.9	12.8	78.5

Probability of no

DEGRADATION	LOSS	ABORT
**	**	**
90% LCL	90% LCL	90% LCL
**	**	**

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	1.0	1.4	2.4
Category II Results	2.1	3.2	5.3

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	424
Shop Active Hours	**	**	191
Total Active Hours	**	**	436
Line Man-Hours	**	**	424
Shop Active Hours	**	**	191
Total Man-Hours	**	**	436

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.5	7.6	1.7	5.0
Shop Man-Hours	7.0	125.2	3.0	17.1
Total Active Hours	5.5	88.4	2.4	11.9
Line Man-Hours	6.5	128.4	3.6	13.8
Shop Man-Hours	18.1	1217.7	6.0	44.9
Total Man-Hours	14.2	887.8	5.0	31.2

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XXIII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
RADAR ALTIMETER – WUC 73C00

HARDWARE RELIABILITY

Predicted MTBF	500
Category II Results	191.5

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
91.0	1283.9	**
90% LCL	90% LCL	90% LCL
63.8	330.1	557.6

Probability of no

DEGRADATION	LOSS	ABORT
.97	1.00	1.00
90% LCL	90% LCL	90% LCL
.96	.99	1.00

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	*	*	*
Category II Results	0.1	0.1	0.2

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.59,0.56	24
Shop Active Hours	W	1.45,0.11	16
Total Active Hours	W	1.17,0.15	26
Line Man-Hours	LN	1.38,0.80	24
Shop Active Hours	LN	1.67,0.91	16
Total Man-Hours	W	1.10,0.08	26

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.4	4.2	2.0	4.0
Shop Man-Hours	4.1	7.8	3.2	7.3
Total Active Hours	4.7	15.9	3.3	8.9
Line Man-Hours	5.6	21.6	4.0	11.3
Shop Man-Hours	8.0	70.5	5.5	14.5
Total Man-Hours	10.1	84.0	8.7	17.3

LN – Log Normal
W – Weibull
EXP – Exponential

Inertial Navigation System (WUC 73H00)

Reliability.

The INS includes the IRU, the navigation computer unit (NCU), two general purpose computers (GPC's), the converter, and other smaller components. Both the mission and hardware reliability of the INS were very low (table XXIV). Earlier in this series of reports, the IRU, GPC, and converter were identified as reliability problems. After that time, the IRU did not demonstrate as much reliability growth as the GPC and converter. TCTO 1F-111-B-A850 changed the IRU from the -91 to the -111 configuration in an attempt to improve reliability. During Category II testing, the -91 IRU measured 95 hours MTBF's are based on a small sample size (three failures for the -91 and six failures for the -111). The data indicates that TCTO 1F-111-B-A-850 may be ineffective in improving IRU reliability.

Maintainability.

The MMH/FH for this subsystem was considered high (table XXIV). While part of this MMH/FH was due to low reliability, there was a maintainability problem with the avionics status/warning lights associated with this subsystem. A full 60 percent of the maintenance actions were initiated because those lights (and possibly other symptoms) did not actually indicate corresponding hardware failures. Some of these maintenance actions may have been software failures that were corrected when the computers were bench-checked and reloaded with programs. The exact percentage was not known, but was suspected to have been a minority of those instances.

Illumination of status/warning lights that could not be duplicated cause considerable unneeded maintenance. An investigation should be conducted to determine the feasibility of improving the accuracy of status/warning lights **(R 1)**[1]

Attack Radar (WUC 73J00)

Reliability.

Both mission and hardware reliability of the AN/APQ-114 attack radar were excellent (table XXV). The majority of the aircrew write-ups concerned function degradations and seldom seriously impacted the missions. Of all write-ups, approximately 22 percent concerned the clock and camera. Further, 35 percent of all aircrew write-ups could not be duplicated by maintenance personnel. It was suspected that the majority of these problems originated with equipments interfacing with the attack radar.

Maintainability.

Although the contractor made no predictions for the attack radar, the MMH/FH shown in table XXV is considered quite reasonable. This figure may increase somewhat in operational use since very little shop (field level) maintenance was done during Category II testing. In most instances, the failed unit was returned to the contractor because of AGE unavailability.

[1] Boldface numerals preceded by an R correspond to the recommendation numbers tabulated in the Conclusions and Recommendations section of this report.

The shop active and manhours was tested and found to fit the Weibull distribution while line man, total active, and total manhours were log-normally distributed.

TABLE XXIV

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT

INERTIAL NAVIGATION SYSTEM – WUC 73H00

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	32.6

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	*	*	*
Category II Results	0.5	0.8	1.3

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
12.3	32.2	257.5
90% LCL	90% LCL	90% LCL
10.0	25.7	154.0

Probability of no

DEGRADATION	LOSS	ABORT
.77	.92	.98
90% LCL	90% LCL	90% LCL
.74	.90	.97

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION
** STATISTIC NOT KNOWN

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	186
Shop Active Hours	**	**	94
Total Active Hours	**	**	191
Line Man-Hours	**	**	186
Shop Active Hours	W	0.66,0.19	94
Total Man-Hours	**	**	191

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.4	5.8	1.5	4.4
Shop Man-Hours	6.5	82.2	3.0	17.8
Total Active Hours	5.5	63.1	2.5	11.4
Line Man-Hours	5.6	54.9	3.0	10.7
Shop Man-Hours	16.8	685.3	7.0	43.7
Total Man-Hours	13.7	502.5	5.5	36.9

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XXV
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
ATTACK RADAR – WUC 73J00

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	286.5

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
22.7	108.8	1087.6
90% LCL	90% LCL	90% LCL
18.7	70.6	279.6

Probability of no

DEGRADATION	LOSS	ABORT
.88	.98	1.00
90% LCL	90% LCL	90% LCL
.86	.96	.99

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	*	*	*
Category II Results	0.3	0.0	0.3

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	58
Shop Active Hours	W	0.53,0.43	30
Total Active Hours	LN	1.13,1.32	58
Line Man-Hours	LN	1.51,1.10	58
Shop Active Hours	W	0.48,0.31	30
Total Man-Hours	LN	1.94,1.78	58

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.7	6.8	1.8	6.3
Shop Man-Hours	8.9	339.7	1.1	17.2
Total Active Hours	7.3	248.4	2.5	15.3
Line Man-Hours	8.4	164.5	4.0	17.3
Shop Man-Hours	25.3	3705.7	2.0	45.1
Total Man-Hours	21.5	2821.6	5.0	49.9

LN – Log Normal
W – Weibull
EXP – Exponential

Terrain Following Radar (WUC 73K00)

Reliability.

The mission and hardware reliability (table XXVI) of the AN/APQ-128 terrain following radar (TFR) was low when compared to MIL-STD-781A statistics. The TFR averaged 1 aircrew write-up every 17 flight hours and about half of these write-ups were considered hardware failures. The remaining write-ups were "cleared" by adjustments or could not be duplicated.

Maintainability.

Although the contractor did not make MMH/FH predictions, the measured MMH/FH (table XXVI) was considered excessive. The line portions of the MMH/FH was high because of the low system reliability while the shop MMH/Fh was attributed both to low reliability and troubleshooting difficulties.

The DOME for line active, line man, total active, and total manhours was tested and found to be log-normally distributed. The shop active and shop manhours were Weibull distributed.

Doppler Radar (WUC 73L00)

Reliability.

The reliability of the AN/APN-185 Doppler radar was lower than the predicted MTBF value (table XXVII). There were 18 aircrew-discovered discrepancies, 8 function degradations, and 10 function losses. The eight function degradations were: one Doppler antenna failure, one electronic unit failure, and six discrepancies that could not be duplicated by the ground crew. The electronic unit failure accounted for all 10 of the function losses.

The electronics units of the Doppler system had the highest failure rate of any component. There were a total of 11 electronic units that failed of which only one was repaired at the line (organizational level), two were repaired at the shop (field level), and eight were sent to the depot for repair. Approximately 30 percent of all discrepancies could not be duplicated by the ground crew.

Maintainability.

The Category II MMH/FH results for this subsystem were quite reasonable, but there are no predicted values for comparison (table XXVII). The line (organizational level) and shop (field level) MMH/FH values were the same. The reason for this is primarily because the electronic unit was the component that failed and very few repairs could be made locally on this unit. The DOME parametric statistics for all types of maintenance except shop manhours were found to be log-normally distributed, while shop manhours was found to be Weibull distributed.

TABLE XXVI

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
TERRAIN FOLLOWING RADAR – WUC 73K00

HARDWARE RELIABILITY

Predicted MTBF	197
Category II Results	74.2

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
17.8	33.6	121.1
90% LCL	90% LCL	90% LCL
14.2	24.5	65.3

Probability of no

DEGRADATION	LOSS	ABORT
.83	.91	.97
90% LCL	90% LCL	90% LCL
.79	.88	.96

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	*	*	*
Category II Results	.5	.9	1.4

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.76,0.70	51
Shop Active Hours	W	0.89,0.16	20
Total Active Hours	LN	1.15,1.33	51
Line Man-Hours	LN	1.32,0.99	51
Shop Active Hours	W	1.89,0.06	20
Total Man-Hours	LN	1.76,1.92	51

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	3.3	23.7	2.0	5.8
Shop Man-Hours	8.1	83.3	5.8	12.0
Total Active Hours	6.5	103.9	2.5	14.0
Line Man-Hours	7.8	444.4	3.5	13.8
Shop Man-Hours	22.5	630.5	15.8	64.6
Total Man-Hours	16.6	1168.2	4.5	33.4

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XXVII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
DOPPLER RADAR – WUC 73L00

HARDWARE RELIABILITY

Predicted MTBF	350.0
Category II Results	121.0

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
46.3	83.4	**
90% LCL	90% LCL	90% LCL
33.7	54.1	362.1

Probability of no

DEGRADATION	LOSS	ABORT
.94	.97	1.00
90% LCL	90% LCL	90% LCL
.92	.95	.99

Operating Hours/Flying Hours Ratio

1.5

* **NO PREDICTION**
** **STATISTIC NOT KNOWN**

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	*	*	*
Category II Results	0.15	0.15	0.3

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.48,0.92	28
Shop Active Hours	LN	0.84,1.60	11
Total Active Hours	LN	0.80,1.46	28
Line Man-Hours	LN	1.06,1.24	3
Shop Active Hours	W	0.50,0.39	1
Total Man-Hours	LN	1.32,1.77	28

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.4	5.2	1.7	5.7
Shop Man-Hours	6.0	124.3	1.1	8.4
Total Active Hours	4.8	72.3	2.1	10.0
Line Man-Hours	5.0	28.8	2.5	14.8
Shop Man-Hours	12.8	813.8	1.5	16.2
Total Man-Hours	10.0	479.5	3.3	19.7

LN – Log Normal
W – Weibull
EXP – Exponential

Astrotracker (WUC 73M00)

Reliability.

The reliability of the AN/ASQ-119 astrocompass was extremely low. The MTBF was nowhere near the predicted value (table XXVIII). There were 22 aircrew-discovered discrepancies: 13 function degradations, and 9 function losses. The 13 degradations were: 5 tracker unit failures, 4 electronics unit failures and 4 discrepancies that could not be duplicated by the ground crew. The nine function losses were: six electronics unit failures, one tracker unit failure, and two discrepancies that could not be duplicated by the ground crew.

There were six tracker unit failures all of which had to be sent to the depot for repair except one which was repaired by replacing several modules. The modules were then sent to the depot for repair. There were 10 electronics unit failures all of which were sent to the depot for repair except for two which were repaired locally. The astrocompass was considered unreliable due to a low hardware reliability, and the utilization rate was not high enough to get an accurate prediction of the reliability of the subsystem.

Maintainability.

The high MMH/FH was due to low hardware reliability. There were many MMH's spent troubleshooting the system by the line (organizational level), and the MMH's for the shop (field level) were also high. The DOME parametric statistics for line active, total active, and total manhours were found to be log-normally distributed; shop active and shop manhours were found to be Weibull distributed, and line manhours were found to be exponentially distributed.

Weapons Delivery (WUC 75000)

Reliability.

Both the hardware and mission reliability of the weapons delivery subsystem was low (table XXIX). Occurring failures were approximately split between the weapons suspension components (pylons and bay) and the weapons control components. The weapons suspension failures were normally discovered between flights and had little impact on mission success. The weapons control failures were usually discovered by the aircrew and were considerably more serious. As a result of control failures there were two aborts for inadvertent releases, two aborts for "no-release" failures, and one abort for a bay door that would not open.

Maintainability.

The measured MMH/FH was twice that predicted (table XXIX). This overage was attributed to low reliability and to difficulties in maintaining the system. A full 37 percent of the aircrew write-ups could not be duplicated and hence produced no positive corrective maintenance action. Following the two inadvertent releases, complete weapons delivery subsystem checkouts were accomplished. One checkout required 160 manhours and the other required 230 manhours.

TABLE XXVIII
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
ASTROTRACKER – WUC 73M00

HARDWARE RELIABILITY

Predicted MTBF	400
Category II Results	14.5

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
13.8	35.3	**
90% LCL	90% LCL	90% LCL
10.4	22.4	138.2

Probability of no

DEGRADATION	LOSS	ABORT
.78	.91	1.00
90% LCL	90% LCL	90% LCL
.72	.87	.98

Operating Hours/Flying Hours Ratio

1.5

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	*	*	*
Category II Results	0.7	1.3	2.0

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.56,0.75	35
Shop Active Hours	W	0.64,0.32	18
Total Active Hours	LN	0.96,1.53	40
Line Man-Hours	EXP	0.18	35
Shop Active Hours	W	0.51,0.30	18
Total Man-Hours	LN	1.52,2.25	40

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	2.4	2.9	1.5	4.9
Shop Man-Hours	8.1	174.9	1.8	19.3
Total Active Hours	5.7	100.8	2.3	12.0
Line Man-Hours	5.3	21.9	4.0	13.8
Shop Man-Hours	20.8	2031.5	3.3	43.1
Total Man-Hours	14.0	1055.2	4.3	25.0

LN – Log Normal
W – Weibull
EXP – Exponential

TABLE XXIX
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
WEAPONS DELIVERY – WUC 75000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	25.6

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
23.7	56.2	90.0
90% LCL	90% LCL	90% LCL
17.5	36.0	35.8

Probability of no

DEGRADATION	LOSS	ABORT
.90	.95	.97
90% LCL	90% LCL	90% LCL
.87	.92	.94

Operating Hours/Flying Hours Ratio

.9

* NO PREDICTION

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	0.2	0.1	0.3
Category II Results	0.5	0.1	0.6

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	LN	0.98,1.25	71
Shop Active Hours	W	0.88,0.34	18
Total Active Hours	LN	1.05,1.26	79
Line Man-Hours	LN	1.76,2.25	71
Shop Active Hours	W	0.73,0.34	18
Total Man-Hours	LN	1.74,2.19	79

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	4.9	36.8	2.0	11.5
Shop Man-Hours	3.7	17.7	1.0	11.2
Total Active Hours	5.3	43.8	2.5	12.5
Line Man-Hours	18.1	1256.6	6.0	39.5
Shop Man-Hours	5.3	53.0	1.3	18.1
Total Man-Hours	17.5	1254.6	5.5	39.5

LN – Log Normal
W – Weibull
EXP – Exponential

Electronic Countermeasures (WUC 76000)

Reliability.

The reliability of this subsystem was extremely low (table XXX). There were 15 aircrew-discovered discrepancies: 12 function degradations, 2 function losses, and 1 mission abort.

During the test program, the penetration aids subsystem demonstrated a MTBF of 12.4 flying hours. The associated 90-percent confidence limit was 8.9 flying hours. A further breakdown of requipment reliability is shown below, where the flying hours, MTBF, and associated 90-percent lower confidence limit are listed for each system within the penetration aids subsystem.

System	Total Flying Hours	MTBF (Flying Hours)	90-Percent Lower Confidence Limit (Flying Hours)
AN/ALQ-94	170.3	34.1	18.7
AN/AAR-34	152.8	38.2	19.1
AN/ALE-28	38.4	38.4	9.9
AN/APS-109A/ ALR-41	198.6	39.7	21.3
Interference Blanker	198.6	198.6	51.6

Maintainability.

Because of the nonrepresentative maintenance performed during testing, no attempt at a quantitative maintainability analysis was made. From a qualitative standpoint, the majority of the maintainability problems encountered were with the AN/ALQ-94.

A large problem area exists in the ability of the go/no-go test on this component. On three flights over instrumented ranges, ground instrumentation determined that the ALQ-94 was not working satisfactorily, but no indication of difficulty was presented to the aircrew. Subsequently, both systems which exhibited these symptoms failed within the next 10 flight hours.

TABLE XXX

RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
ELECTRONIC COUNTERMEASURES – WUC 76000

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	12.4

SUBSYSTEM MISSION RELIABILITY

Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
10.8	46.9	140.6
90% LCL	90% LCL	90% LCL
7.0	21.5	35.2

Probability of no

DEGRADATION	LOSS	ABORT
.68	.91	.97
90% LCL	90% LCL	90% LCL
.58	.83	.91

Operating Hours/Flying Hours Ratio

1.0

* NO PREDICTION
** STATISTIC NOT KNOWN

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	*	*	*
Category II Results	*	*	*

DISTRIBUTION OF MAINTENANCE EVENTS

Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	**
Shop Active Hours	**	**	**
Total Active Hours	**	**	**
Line Man-Hours	**	**	**
Shop Active Hours	**	**	**
Total Man-Hours	**	**	**

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	**	**	**	**
Shop Man-Hours	**	**	**	**
Total Active Hours	**	**	**	**
Line Man-Hours	**	**	**	**
Shop Man-Hours	**	**	**	**
Total Man-Hours	**	**	**	**

LN – Log Normal
W – Weibull
EXP – Exponential

OVERALL AIRCRAFT

Reliability

Hardware Reliability.

The overall reliability of the FB-111A aircraft in terms of hardware failures was 1.6 hours MTBF (table XXXI). This figure is optimistic because not all subsystems were operated during a significant percentage of the accumulated flight hours. The subsystems that only accumulated a small percentage of the total flight hours biased the hardware MTBF value.

Because of the multiple configurations of most subsystems and the widely varying size and utilization rate of Category II fleet, it was not possible to determine if any substantial reliability growth existed during Category II test. The lack of contractor predictions for hardware reliability made it impossible to measure the aircraft against any design goals.

Mission Reliability.

During the Category II test program the aircraft demonstrated a MFHBFD of 1.5 flight hours. The number of ground-crew-discovered hardware failures was approximately the same as the number of aircrew write-ups that did not yield a hardware failure. As a result, the hardware MTBF was about equal to the MFHBFD. The aircraft demonstrated a Mean Time Between Function Losses of 5.0 flight hours. Again, these statistics were biased upwards by the low flight hours accumulated on some subsystems. Appendix I shows the flight hours accumulated on each subsystem and also summarizes the mission reliability statistics by subsystem.

Maintainability

Support General (Scheduled) Maintenance.

The contractor predicted 6.3 MMH/FH for support general maintenance (WUC groups 01 through 09) and 22.9 MMH/FH would be required during Category II testing. Any comparison of support general MMH/FH's must consider the following usage restrictions (abstracted from: Maintainability Specification for Model FB-111A Weapon System, reference 19):

> "Military usage in excess of 2.8 MMH/FH shall not be chargeable to the contractor MMH/FH requirement. Military usage shall include all labor expended under WUC's 02, 05, 06, 07, 08, 09, that portion of code 01, Ground Handling and Service (ground handling only) and that portion of code 04, Special Inspections (Special Inspection for Modification, Test Flight, After Fire, Excessive 'g', Hand Loading and Hot Start; Engine Time, Weight and Balance, Compass Swing, Accident/Incident Investigation, Reclamation, Emergency Equipment Check DD 780 Inventory)."

Censoring the Category II data to meet this restriction yielded a measured MMH/FH of 13.0. The remaining difference is attributed entirely to unrealistic contractor predictions.

TABLE XXXI
RELIABILITY AND MAINTAINABILITY FIGURES OF MERIT
OVERALL AIRCRAFT

HARDWARE RELIABILITY

Predicted MTBF	*
Category II Results	1.6

MAINTAINABILITY

	LINE	SHOP	TOTAL
Contractor Predicted MMH/FH	17.5	6.3	23.8
Category II Results	38.1	10.7	48.8

SUBSYSTEM MISSION RELIABILITY
Mean Flight Hours Between

DEGRADATIONS	LOSSES	ABORTS
1.74	6.34	24.2
90% LCL	90% LCL	90% LCL
1.2	4.7	19.6

Probability of no

DEGRADATION	LOSS	ABORT
**	**	**
90% LCL	90% LCL	90% LCL
**	**	**

Operating Hours/Flying Hours Ratio

**

DISTRIBUTION OF MAINTENANCE EVENTS
Parametric Statistics

TYPE MAINTENANCE	DISTRIBUTION	PARAMETER(S)	SAMPLE SIZE
Line Active Hours	**	**	1920
Shop Active Hours	LN	1.31,1.51	498
Total Active Hours	**	**	1999
Line Man-Hours	LN	1.45,1.62	1920
Shop Active Hours	LN	1.95,2.45	498
Total Man-Hours	LN	1.69,2.02	1999

Non-Parametric Statistics

TYPE MAINTENANCE	MEAN	VARIANCE	MEDIAN	M_{max}
Line Active Hours	3.8	114.9	2.0	7.9
Shop Man-Hours	8.0	163.6	3.5	17.9
Total Active Hours	5.6	165.9	2.5	11.5
Line Man-Hours	10.7	831.8	4.0	21.8
Shop Man-Hours	22.2	1931.3	7.0	55.3
Total Man-Hours	15.8	1398.8	5.0	36.8

* NO PREDICTION
** STATISTIC NOT KNOWN

LN – Log Normal
W – Weibull
EXP – Exponential

Nonsupport General (Unscheduled) Maintenance.

The contractor predicted 17.5 MMH/FH for nonsupport maintenance (WUC's 11 through 99), and 25.8 MMH/FH was required during Category II testing. Of the measured value, 4.6 MMH/FH was required for TCTO accomplishment. Even if TCTO requirements decrease as the weapons system matures, a remaining difference of 3.7 MMH/FH would be expected. Since the nonavionics subsystems (with the flight controls excepted) generally met contractor predictions and the avionics subsystems (with the communications subsystems excepted) exceeded predictions, reliability improvements in the flight controls and avionics subsystem should allow the air vehicle to meet maintainability predictions for unscheduled maintenance. Table XXXII shows the measured MMH/FH by Work Unit Code.

Table XXXII

MMH/FH SUMMARY

Title	WUC	Line MMH/FH	Shop MMH/FH	Total MMH/FH
Support General Maintenance Actions				
GND HANDLING, SERVICE, FLY	01000	10.1	0.0	10.1
AIRCRAFT CLEANING	02000	0.7	0.0	0.7
LOOK PHASE OF INSPECTION	03000	7.7	0.0	7.7
SPECIAL INSPECTIONS	04000	1.6	0.8	2.4
ACFT AND ENGINE STORAGE	05000	0.0	0.1	0.1
GROUND SAFETY	06000	0.1	0.0	0.1
PREPARATION ACFT RECORDS	07000	0.4	0.0	0.4
SPECIAL WPNS HANDLING	08000	0.0	0.0	0.0
SHOP SUPPORT GENERAL	09000	0.0	1.2	1.3
Totals for Support General		10.1	0.6	10 7
Nonsupport General Maintenance Actions				
AIRFRAME	11000	2.8	0.1	[illegible]9
LANDING GEAR	13000	1.3	0.1	1.4
FLIGHT CONTROL	14000	3.7	0.3	4 0
ESCAPE CAPSULE	16000	1.2	0.0	1.2
TURBO JET POWER PLANT	23000	0.9	0.5	1.4
AIR CONDITION, PRESSURE	41000	0.7	0.0	0.7
ELECTRICAL POWER SUPPLY	42000	0.1	0.0	0.1
LIGHTING SYSTEM	44000	0.0	0.0	0.1
PNEUDRAULIC POWER SUPPLY	45000	0.4	0.0	0.4
FUEL SYSTEM	46000	0 4	0.0	0.4
OXYGEN SYSTEM	47000	0.0	0.0	0 0
MISCELLANEOUS UTILITIES	49000	0.0	0.0	0.0
INSTRUMENTS	51000	0.8	0.9	1.7
AUTOPILOT	52000	0.9	0.9	1.8
HF COMMUNICATIONS	61000	0.1	0.3	0.4
UHF COMMUNICATIONS	63000	0.2	0.0	0.2
INTERPHONE	64000	0.1	0.0	0.1
IFF/SIF	65000	0.0	0.1	0 1
MISC COMM EQUIPMENT	69000	0.1	0.0	0.1
RADIO NAVIGATION	71000	0.2	0.4	0.6
BOMBING NAVIGATION	73000	2.1	2.8	4.9
FIRE CONTROL	74000	0.0	0.0	0.0
WEAPONS DELIVERY	75000	0.5	0.1	0.6
ELECTRONIC COUNTERMEASURE	76000	0.5	1.4	1.9
PERSONNEL EQUIPMENT	96000	0.0	0.0	0.0
EXPLOSIVE DEVICES	97000	0.2	0.0	0.2
Totals for Nonsupport General		17.1	8.2	25.3
FB-111A Aircraft Totals		37.7	10.3	48.0

AVAILABILITY

Aircraft availability is a measure of the degree to which an aircraft is in the operable and commitable state at the start of the mission, when the mission is called for at an unknown (random) point in time. Inherent availability is a function of aircraft reliability, the effectiveness of maintainability design, and the adequacy of the contractor-recommended number of maintenance personnel, spares, AGE, and technical orders, but not the operational environment. Inherent availability can be expressed by the formula:

$$A_i = \frac{\text{Total Time} - \text{Active Repair Time}}{\text{Total Time}}$$

For ease of computing the active repair time the following formula was used:

$$A_i = \frac{AH/MON - \frac{MART}{FLT}\ \frac{FH}{MON}\ \frac{FLT}{FH} + \frac{MAPT}{PI}\ \frac{PI}{FH}\ \frac{FH}{MON}}{AH/MON}$$

where,

A_i = inherent aircraft availability

AH/MON = active hour per month that the aircraft was available for flying and/or maintenance

MART/FLT = mean active hours to repair the aircraft between successive flights

MAPT/PI = mean active hours required to complete a phase inspection.

FLT/FH = number of flights per hour.

FH/MON = number of flight hours per month.

PI/FH = number of phase inspections per flight hour.

The MART/FLT and the MAPT/PI were calculated using only active maintenance times, since administrative and logistic delays were a function of the maintenance management at each operational unit and therefore must be excluded from any calculation of inherent availability.

The following calculations use:

MAPT/FLT = 4.0 active hours per flight

MAPT/PI = 36.0 active hours per phase inspection

and the following assumptions:

AH/MON = 16 hours per day for 22 days per month
= 352 active hours per month

FH/MON = 30 flight hours per month

FLT/FH = 0.5 flight per flight hour (2-hour average flight deviation)

PI/FH = 0.04 phase inspection/flight hour (a constant)

Giving:

$$A_i = \frac{352 - [(4.0)(30)(0.5) + (36.0)(0.04)(30)]}{352}$$

$$= \frac{352 - (60.0 + 43.2)}{352}$$

$$= 70.5 \text{ percent.}$$

Because the above assumptions may be unrealistic for an operational unit, figures 1, 2, and 3 are presented. Each graph plots A_i as a function of active hours per day with separate curves for average flight durations of 2, 4, and 6 hours. Figure 1 assumes 20 flight hours per month while figures 2 and 3 assume 30 and 40 flight hours per month respectively.

Figures 1, 2, and 3 are on the following pages

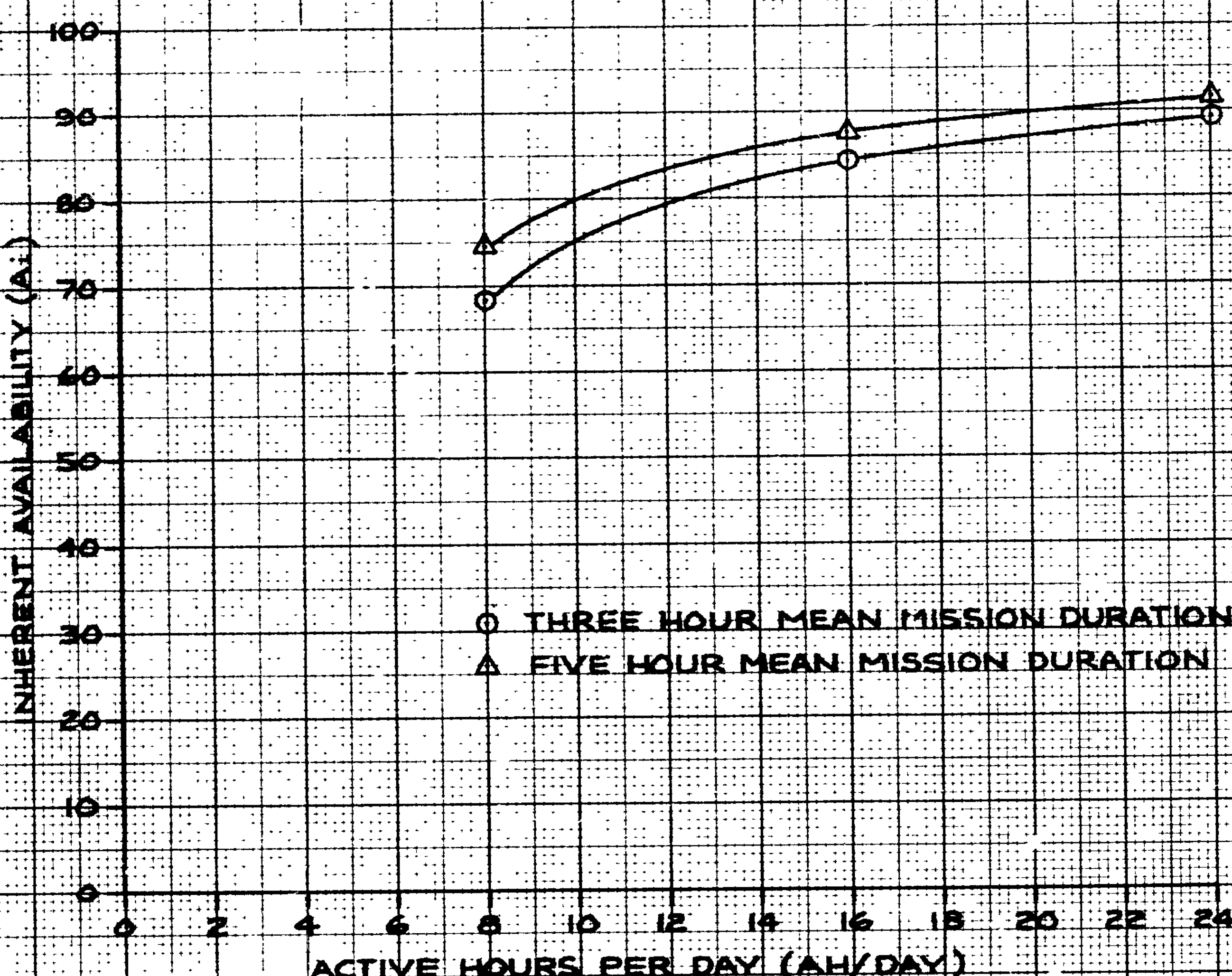


FIGURE 1
INHERENT AVAILABILITY
FOR 20 FLIGHT HOURS PER MONTH (FH/MON)

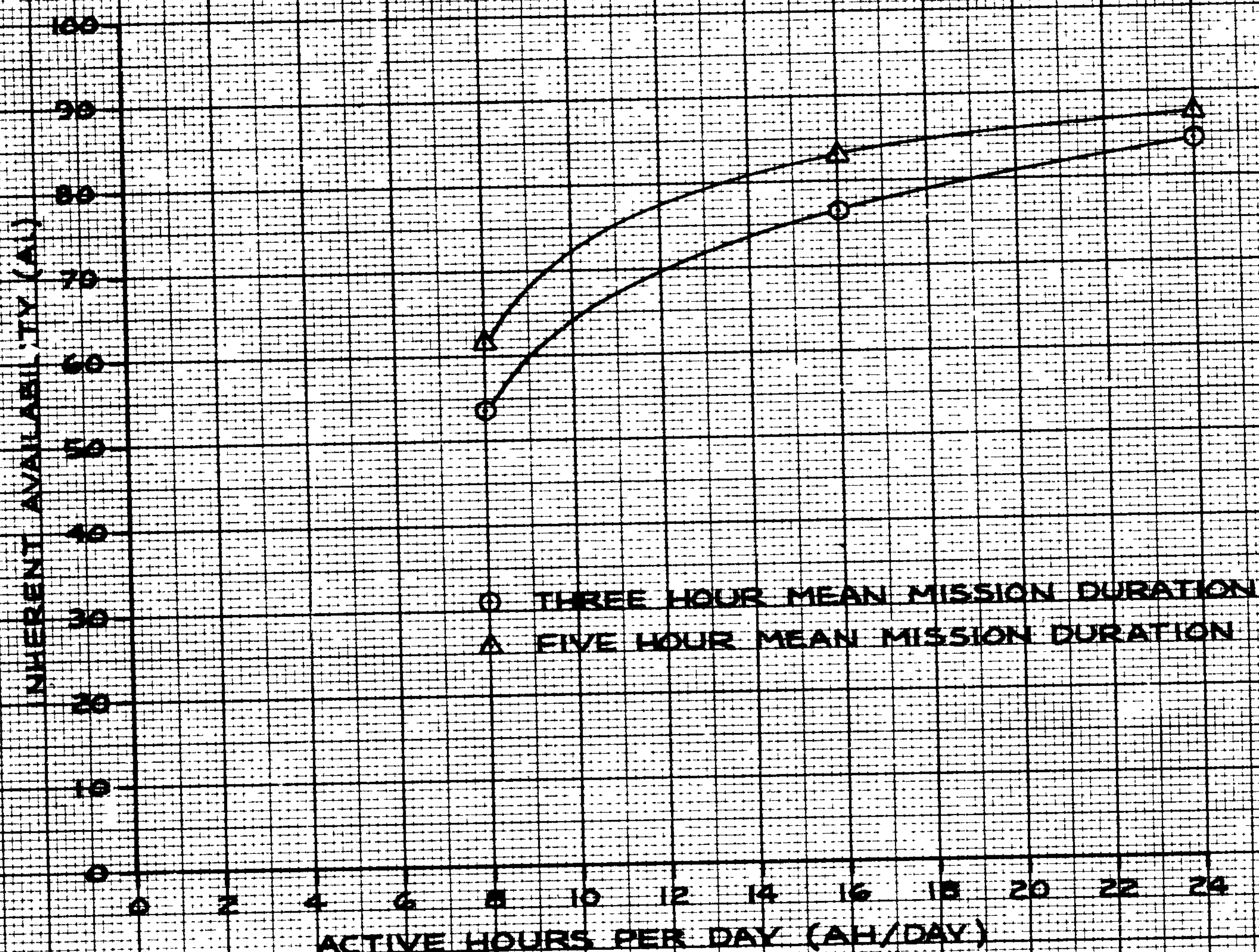


FIGURE 2
INHERENT AVAILABILITY
FOR 30 FLIGHT HOURS PER MONTH (FH/MON)

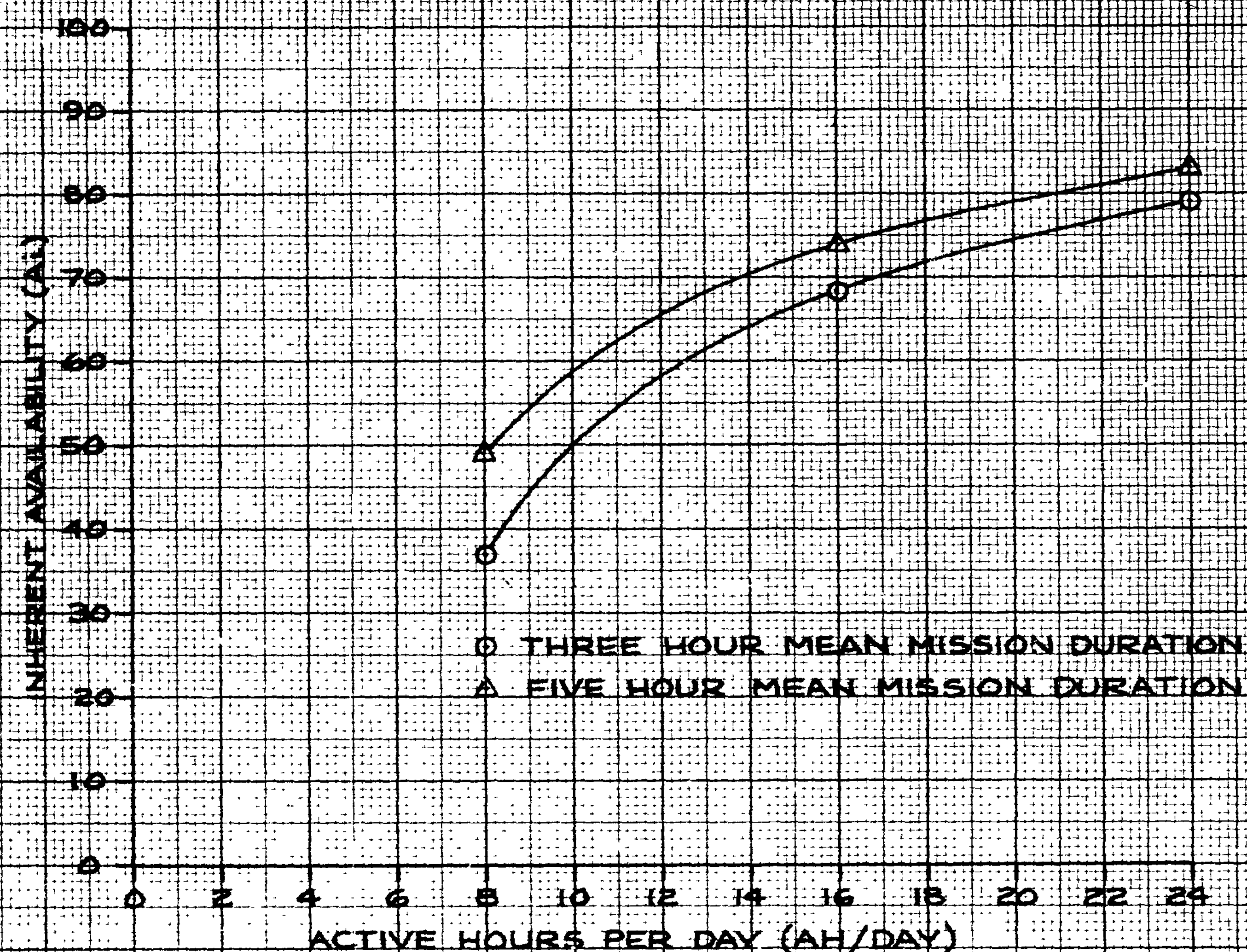


FIGURE 3
INHERENT AVAILABILITY
FOR 40 FLIGHT HOURS PER MONTH (FH/MON)

CONCLUSIONS AND RECOMMENDATION

RELIABILITY

The overall reliability of the FB-111A aircraft in terms of hardware failures was 1.6 hours MTBF. This figure is optimistic because not all subsystems were operated during a significant percentage of the accumulated flight hours. The subsystems that only accumulated a small percentage of the total flight hours biased the hardware MTBF value.

During the Category II test program the aircraft demonstrated a mean flying hours between function degradation of 1.5 flight hours. The number of ground-crew-discovered hardware failures was approximately the same as the number of aircrew writeups that did not yield a hardware failure. As a result, the hardware MTBF was about equal to the MFHBFD. The aircraft demonstrated a Mean Time Between Function Losses of 5.0 flight hours. Again, these statistics were biased upwards by the low flight hours accumulated on some subsystems.

With the exception of the flight controls subsystem, the reliability of the nonavionics subsystems was considered acceptable. Should modifications incorporated into the aircraft prove effective, the flight controls subsystems should approach satisfactory reliability.

The reliability of the avionics subsystems was low (with the exception of the attack radar) when compared with qualification test statistics that applied to MIL-STD-781A testing.

Because of the multiple configurations of most subsystems and the widely varying size and utilization rate of Category II fleet, it was not possible to determine if any substantial reliability growth existed during Category II test. The lack of contractor predictions for hardware reliability made it impossible to measure the aircraft against any design goals.

MAINTAINABILITY

The contractor predicted that an MMH/FH of 6.3 would be required for support general maintenance (WUC groups 01 through 09); 22.9 MMH/FH was required during Category II testing.

Censoring the Category II data to meet restrictions on military usage as defined in the text (page   ) yielded a measured MMH/FH of 13.0. The remaining difference is attributed entirely to unrealistic contractor predictions.

The contractor predicted 17.5 MMH/FH for nonsupport maintenance (WUC's 11 through 99), and 25.8 MMH/FH was required during Category II testing. Of the measured value, 4.6 MMH/FH was required for TCTO accomplishment. Even if TCTO requirements decrease as the weapons system matures, a remaining difference of 3.7 MMH/FH would be expected. Since the nonavionics subsystems (with the flight controls excepted) generally met contractor predictions and the avionics subsystems (with the communications subsystems excepted) exceeded predictions, reliability improve-

ments in the flight controls and avionics subsystem should allow the air vehicle to meet maintainability predictions for unscheduled maintenance.

There was a high "cannot duplicate" rate for some subsystems due to altitude, temperature, or g-related malfunctions.

Within the inertial navigation subsystems, 60 percent of the maintenance actions initiated because of status-warning lights (and possibly other symptoms) did not trace to a hardware failure.

1. An investigation should be conducted to determine the feasibility of improving the accuracy of status/warning lights (page 40).

APPENDIX I

GENERAL INFORMATION

FB111A CATEGORY II
AIRCREW EVALUATION SUMMARY

	FUNCTION SUCCESS	FUNCTION DEGRADATION	FUNCTION LOSS	MISSION ABORT	TIME (HOURS)
AIRFRAME	477	18	3	1	1308.06
LANDING GEAR	488	9	2	2	1308.06
FLIGHT CONTROL	455	24	16	10	1308.06
ESCAPE CAPSULE	494	4	0	0	1303.65
TURBO-JET ENGINE	452	42	2	8	1308.06
AIR COND + PRESS	467	24	2	0	1295.81
ELECTRICAL POWER	496	3	0	1	1308.06
LIGHTING SYSTEM	483	13	3	0	1308.06
HYD + PNEU POWER	492	4	1	3	1308.06
FUEL	473	23	0	1	1302.37
AIR REFUELING	53	5	0	0	279.91
OXYGEN SYSTEM	496	2	0	0	1304.81
MISC UTILITIES	497	0	0	0	1305.06
INSTRUMENTS	424	63	9	1	1296.94
AUTOPILOT	434	31	6	8	1265.17
AIR DATA	492	4	1	1	1303.23
HF COMM	173	6	7	0	600.78
UHF COMM	450	40	4	1	1295.70
INTERPHONE	486	12	0	0	1303.90
IFF/SIF	479	6	6	0	1293.31
MISC COMM EQUIP	495	1	0	0	1304.80
TACAN	464	12	5	0	1277.18
ILAS	121	4	1	0	392.73
UHF/ADF	11	0	0	0	44.32
RNDZ BEACON	51	7	0	0	279.04
INERTIAL NAV	432	28	22	5	1286.48
ATTACK RADAR	363	38	9	1	1087.61
RADAR ALTIMETER	473	13	1	0	1283.95
TFR	163	16	13	5	605.64
DOPPLER	296	8	10	0	833.70
ASTRO-TRACKER	80	14	9	0	318.10
DISPLAY SUBSYSTE	458	4	0	0	1233.33
ODS	427	3	0	0	1136.00
DUAL BOMB TIMER	13	0	0	0	35.09
COMPUTER COMPLEX	394	42	13	0	1202.03
PYLONS	204	0	0	0	551.82
WEAPONS BAY	94	5	1	0	228.65
WEAPONS CONTROL	177	5	0	3	449.29
WEAPONS RACKS	183	1	2	2	456.36
TRACK BREAKER	30	1	1	0	125.81
CMRS	25	3	0	1	107.13
CMDS	4	0	0	0	20.06
RHAWS	29	7	1	0	140.59
INSTRUMENTATION	377	11	8	6	1078.92

FB111 CATEGORY II
AIRCREW EVALUATION ANALYSIS-(PART 1)

	MEAN HOURS BETWEEN FUNCTION DEGRADATION		MEAN HOURS BETWEEN FUNCTION LOSS		MEAN HOURS BETWEEN MISSION ABORT	
	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT
AIRFRAME	59.5	44.6	327.0	163.6	1308.1	336.3
LANDING GEAR	100.6	69.0	327.0	163.6	654.0	245.8
FLIGHT CONTROL	26.2	21.7	50.3	38.7	130.8	84.9
ESCAPE CAPSULE	325.9	163.1	NO LOSS	566.2	NO ABORT	566.2
TURBO-JET ENGINE	25.2	20.9	130.8	84.9	163.5	100.7
AIR COND + PRESS	49.8	38.3	647.9	243.5	NO ABORT	562.8
ELECTRICAL POWER	327.0	163.5	1308.1	336.3	1308.1	336.3
LIGHTING SYSTEM	81.8	58.3	436.0	195.8	NO ABORT	568.1
HYD + PNEU POWER	163.5	100.7	327.0	163.6	436.0	195.8
FUEL	54.3	41.2	1302.4	334.8	1302.4	334.8
AIR REFUELING	56.0	30.2	NO LOSS	121.6	NO ABORT	121.6
OXYGEN SYSTEM	652.4	245.2	NO LOSS	566.7	NO ABORT	566.7
MISC UTILITIES	NO DEGD	566.8	NO LOSS	566.8	NO ABORT	566.8
INSTRUMENTS	17.8	15.2	129.7	84.2	1296.9	333.4
AUTOPILOT	28.1	23.1	90.4	62.9	158.1	97.4
AIR DATA	217.2	123.7	651.6	244.9	1303.2	335.1
HF COMM	46.2	31.7	85.8	51.0	NO ABORT	260.9
UHF COMM	28.8	23.6	259.1	139.7	1295.7	333.1
INTERPHONE	108.7	73.3	NO LOSS	566.3	NO ABORT	566.3
IFF/SIF	107.8	72.7	215.6	122.8	NO ABORT	561.7
MISC COMM EQUIP	1304.8	335.5	NO LOSS	566.7	NO ABORT	566.7
TACAN	75.1	54.1	255.4	137.7	NO ABORT	554.7
ILAS	78.5	42.3	392.7	101.0	NO ABORT	170.6
UHF/ADF	NO DEGD	19.2	NO LOSS	19.2	NO ABORT	19.2
RND7 BEACON	39.9	23.7	NO LOSS	121.2	NO ABORT	121.2
INERTIAL NAV	23.4	19.6	47.6	36.8	257.3	138.7
ATTACK RADAR	22.7	18.7	108.8	70.6	1087.6	279.6
RADAR ALTIMETER	91.7	63.8	1283.9	330.1	NO ABORT	557.6
TFR	17.8	14.2	33.6	24.5	121.1	65.3
DOPPLER	46.3	33.7	83.4	54.1	NO ABORT	362.1
ASTRO-TRACKER	13.8	10.4	35.3	22.4	NO ABORT	138.2
DISPLAY SUBSYSTE	308.3	154.3	NO LOSS	535.6	NO ABORT	535.6
ODS	378.7	170.0	NO LOSS	493.4	NO ABORT	493.4
DUAL BOMB TIMER	NO DEGD	15.2	NO LOSS	15.2	NO ABORT	15.2
COMPUTER COMPLEX	21.9	18.3	92.5	63.4	NO ABORT	522.1
PYLONS	NO DEGD	239.7	NO LOSS	239.7	NO ABORT	239.7
WEAPONS BAY	38.1	21.7	228.6	58.8	NO ABORT	99.3
WEAPONS CONTROL	56.2	34.6	149.8	67.3	149.8	67.3
WEAPONS RACKS	91.3	49.2	114.1	57.1	228.2	85.7
TRACK BREAKER	62.9	23.6	125.9	32.3	NO ABORT	54.6
CMPS	26.8	13.4	107.1	27.5	107.1	27.5
CMDS	NO DEGD	8.7	NO LOSS	8.7	NO ABORT	8.7
RHAWS	17.6	10.8	146.6	36.1	NO ABORT	61.1
INSTRUMENTATION	43.2	33.0	77.1	53.6	179.8	102.4

FB111 CATEGORY II
AIRCREW EVALUATION ANALYSIS-(PART 2)

	PROBABILITY OF NO FUNCTION DEGRADATION		PROBABILITY OF NO FUNCTION LOSS		PROBABILITY OF NO MISSION ABORT	
	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT	MEASURED	90 PERCENT LOWFR CONFIDENCF LIMIT	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT
AIRFRAME	.96	.94	.99	.99	1.00	.99
LANDING GEAR	.97	.96	.99	.99	1.00	.99
FLIGHT CONTROL	.90	.88	.95	.93	.98	.97
ESCAPE CAPSULE	.99	.98	1.00	1.00	1.00	1.00
TURBO-JET ENGINE	.90	.88	.98	.97	.98	.98
AIR COND + PRESS	.95	.93	1.00	.99	1.00	1.00
ELECTRICAL POWER	.99	.99	1.00	.99	1.00	.99
LIGHTING SYSTEM	.97	.96	.99	.99	1.00	1.00
HYD + PNEU POWER	.98	.98	.99	.99	.99	.99
FUEL	.95	.94	1.00	.99	1.00	.99
AIR REFUELING	.91	.85	1.00	.97	1.00	.97
OXYGEN SYSTEM	1.00	.99	1.00	1.00	1.00	1.00
MISC UTILITIES	1.00	1.00	1.00	1.00	1.00	1.00
INSTRUMENTS	.85	.83	.98	.97	1.00	.99
AUTOPILOT	.91	.89	.97	.96	.98	.97
AIR DATA	.99	.98	1.00	.99	1.00	.99
HF COMM	.93	.90	.96	.94	1.00	.99
UHF COMM	.91	.89	.99	.98	1.00	.99
INTERPHONE	.98	.97	1.00	1.00	1.00	1.00
IFF/SIF	.98	.96	.99	.98	1.00	1.00
MISC COMM EQUIP	1.00	.99	1.00	1.00	1.00	1.00
TACAN	.96	.95	.99	.98	1.00	1.00
ILAS	.96	.93	.99	.97	1.00	.99
UHF/ADF	1.00	.81	1.00	.81	1.00	.81
RNDZ BEACON	.89	.81	1.00	.97	1.00	.97
INERTIAL NAV	.89	.87	.94	.93	.99	.98
ATTACK RADAR	.88	.86	.98	.96	1.00	.99
RADAR ALTIMETER	.97	.96	1.00	.99	1.00	1.00
TFR	.83	.79	.91	.88	.97	.96
DOPPLER	.94	.92	.97	.95	1.00	.99
ASTRO-TRACKER	.78	.72	.91	.87	1.00	.98
DISPLAY SUBSYSTE	.99	.98	1.00	1.00	1.00	1.00
ODS	.99	.99	1.00	1.00	1.00	1.00
DUAL BOMB TIMER	1.00	.84	1.00	.84	1.00	.84
COMPUTER COMPLEX	.88	.86	.97	.96	1.00	1.00
PYLONS	1.00	.99	1.00	.99	1.00	.99
WEAPONS BAY	.94	.90	.99	.97	1.00	.98
WEAPONS CONTROL	.96	.93	.98	.97	.98	.97
WEAPONS RACKS	.97	.95	.98	.96	.99	.97
TRACK BREAKER	.94	.86	.97	.90	1.00	.95
CMRS	.86	.74	.97	.87	.97	.87
CMDS	1.00	.56	1.00	.56	1.00	.56
RHAWS	.78	.69	.97	.91	1.00	.96
INSTRUMENTATION	.94	.92	.97	.95	.99	.98

APPENDIX II
DATA COLLECTION AND FORMULAE

OPERATIONAL DATA SYSTEM

Reliability data were collected by use of the Aircraft Debriefing Record (AFFTC Form 0-294), figure 4. The reliability and maintainability (R&M) engineer or his designated representative recorded the crewmember's analysis of subsystem deficiencies and malfunctions that occurred during the mission on the AFFTC Form 0-294. These reliability codes were used to record debriefing of the aircrew:

No entry	System was not used.
1	System operated satisfactorily.
2	System malfunctioned (was of degraded operation requiring corrective maintenance action), but was still capable of performing its intended function to a level at which the mission objectives for this subsystem were still accomplished.
3	System was completely inoperative or a required mode of operation was inoperative (in the minimum specified performance of the subsystem was not attained), but the failure did not cause an abort.
4	System failure as defined by 3 above that caused an abort.
5	Mission was flown with a known system discrepancy. If a new unrelated discrepancy occurred or system operation was satisfactory except for the known discrepancy, the appropriate code was entered.

The following definitions of mission effectiveness were used:

1. Ground Abort - Anytime the engine was shut down after engine start. Anytime maintenance was required before the pilot would take the aircraft, for example, adjustment of the system to obtain a usable presentation.

2. Air Abort - Anytime the aircraft was landed before normal mission completion for any safety-of-flight reason. Whenever the primary preplanned mission could not be performed due to a subsystem failure.

This form was also used to summarize the maintenance actions required to correct flight discrepancies. The R&M engineer evaluated each discrepancy after maintenance action was completed to determine whether it was a valid failure, discrepancy, etc., before including the information in the master history file.

Next the forms were keypunched and entered into the reliability master history file and a computerized listing of all data by mission was output. The R&M engineer edited this data product and corrected any data errors before performing any analysis on this file.

AIRCRAFT DEBRIEFING RECORD

TYPE (FB-111A)

CARD NO	1 AIRCRAFT TYPE	2 ID SERIAL NO.	3 MISSION NO	4 DATE DAY MONTH YEAR	5 T O TIME HOUR MIN	6 DURATION HOUR MIN	7 TYPE MISSION	8 MSN EFFECT	9 LANDINGS
1	F B 1 1 1 A	A							

10 HIGH MACH	11 HIGH ALT	12 AIR REFUEL THOU LB TRANS	13 AIR REFUEL CONTACTS	14 SUPER TIME HR MIN	15 WING SWEEPS	16 O.R.M. BELOW 1000 HOUR MIN	17

18 PILOT	19 NAVIGATOR	20

CARD NO.	BLOCK NO	REL CODE	SYSTEM NAME	CARD NO	BLOCK NO	REL CODE	SYSTEM NAME
2	21		AIRFRAME	2	51		INERTIAL NAVIGATION
	22				52		ATTACK RADAR
	23		LANDING GEAR		53		RADAR ALTIMETER
	24		FLIGHT CONTROL		54		TFR
	25		ESCAPE CAPSULE		55		DOPPLER
	26		TURBO-JET ENGINE		56		ASTRO-TRACKER
	27		AIR CONDITIONING & PRESSURIZATION		57		DISPLAY SUBSYSTEM
	28		ELECTRICAL POWER		58		CDS
	29		LIGHTING SYSTEM		59		DUAL INDICATING BOMB TIMER
	30		HYDRAULIC & PNEUMATIC POWER		60		COMPUTER COMPLEX
	31		FUEL		61		
	32		AIR REFUELING		62		
	33				63		PYLONS
	34		OXYGEN SYSTEM		64		WEAPONS BAY
	35		MISCELLANEOUS UTILITIES		65		WEAPONS CONTROL
	36		INSTRUMENTS		66		WEAPONS RACKS
	37				67		
	38		AUTO PILOT		68		TRACK BREAKER SYSTEM
	39		AIR DATA		69		CMRS
	40		HF COMMUNICATIONS		70		CMDS
	41		UHF COMMUNICATIONS		71		RHAWS
	42		INTERPHONE		72		
	43		IFF/SIF		73		
	44		MISCELLANEOUS COMMUNICATION EQUIPMENT		74		INSTRUMENTATION
	45		TACAN		75		
	46		ILAS		76		
	47		UHF/ADF		77		
	48		RNDZ BEACON		78		
	49				79		
	50				80		

MISSION OBJECTIVES	% SUCCESS

SIGNATURE OF AIRCRAFT COMMANDER	SIGNATURE OF DEBRIEFER

CODE FOR BLOCKS AS INDICATED

BLOCK 7 (TYPE MISSION)	BLOCK 8 (MISSION EFFECTIVENESS)	RELIABILITY CODES
01 TRANSITION OR TRAINING	1 FLOWN AS BRIEFED	BLANK EQUIPMENT NOT USED
02 TEST SUPPORT	2 MISSION DEVIATION	1 OPERATED SATISFACTORILY
03 OTHER SUPPORT	3 AIR ABORT	2 DEGRADED OPERATION
04 SYSTEMS TEST	4 GROUND ABORT	3 FAILED BUT NO ABORT
05 PERFORMANCE TEST	5 FLOWN AS BRIEFED & ADDITIONAL EVALUATION PERFORMED	4 FAILED AND ABORT
06 STABILITY AND CONTROL TEST	NOTE: MISSIONS CHANGED FOR OTHER THAN MAINTENANCE ARE CODED 1.	5 FLOWN WITH KNOWN DISCREPANCY

AFFTC FORM OCT 68 O-294

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

Figure 4 Aircraft Debriefing Record

DISCREPANCIES [1]

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

CARD	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN
3											

DESCRIPTION OF DISCREPANCY

[1] *NOTE:*

a *Obtain Block Number from front of this form.*

b *Obtain Job Control Number, When Discovered Code, Work Unit Code, How Malfunctioned Code, and Action Taken Code from AFSC Form 258/AFTO Form 349 as applicable, which shows the primary cause of failure*

Figure 4 Aircraft Debriefing Record (Concluded)

The Operating Time Report for Selected Items (AFTO Form 4), figure 5, recorded the elapsed time indicator (ETI) readings for each item so equipped during each scheduled phase inspection. These readings were compared to aircraft flight hours to obtain a ratio of the subsystem operating hours to the aircraft flight hours. The final cumulative ratio of these times is presented in table I. The value presented for those subsystems which did have ETI's represented the R&M engineer's estimate of this ratio from known run-up time, maintenance times, etc.

OPERATING TIME REPORT FOR SELECTED ITEMS	1 MDS FB-111A	2 TAIL #	3 A/C TIME	4	5 DATE / /	

A	B	C	WUC D	E	ITEM NOMENCLATURE F	ITEM PART NUMBER G	ITEM SERIAL NUMBER H	I	INSTALLED ITEM ETI READING J	K	FAILED ITEM DATA: ETI READING AT REMOVAL L	FAILED ITEM DATA: JULIAN DATE M	FAILED ITEM DATA: HOW MAL CODE N	FAILED ITEM DATA: ACTION TAKEN O
			52AAA		Comp, Flt C., Roll	273E760G1								
			52ABA		Comp, Flt C, Pitch	273E750G1								
			52ACA		Comp, Flt C, Yaw	273E770G1								
			52ADA		Feel Trim Assy	12C1154-839								
			52BAA		Comp, Ctr Air Data	1903634-3								
			52BBR		Mach Assy, Max Safe	12C1006-817								
			61AA0		Rec'r Trans, HF	342626								
					RT-822/ARC-123									
			61AB0		Amp, Power Supply	342626								
					AM-4573/ARC-123									
			63AA0		Rec'r Trans, UHF #1	522-4304-001								
					RT-749/ARC-109									
			63AA0		Rec'r Trans, UHF #2	522-4304-001								
			65AAA		Rec'r Trans, IFF	113590-1								
					RT-728/APX-64V									
			71AA0		Rec'r Trans, TACAN	54500306-2								
					RT-3841/ARN-52V									
			73CA0		Rec'r Trans, Rdr Alt	HG7092A3								
					RT-771/APN-167									
			73CA0		Rec'r Trans, Rdr Alt	HG7092A3								
					RT-771/APN-167									
			73HA0		Internal Ref Unit	68144-301-31								
			73HC0		Nav Computer	55545-107-11								
			73HG0		Computer #1	6861600								
			73HG0		Computer #2	6861600								
			73HJ0		Converter	C704772081								
			73JC0		Rec'r Trans Mod	7335134G4								
			73JH0		Sync, (APQ-114)	7335135G3								
			73KA0		Comp, TF Lt, APQ-128	562182-12								
			73KA0		Comp, TF Rt, APQ-128	562182-12								
			73KE0		Amp, Pwr Sup,APQ-128	582357-10								
			73KE0		Amp, Pwr Sup,APQ-128	582357-10								
			73KF0		Syn-Trans, APQ-128	582358-1								
			73KF0		Syn-Trans, APQ-128	582358-1								
			73MB0		Elect. Unit, ASG-25	668500-7								
			74ACA		Sight, Optical	852D530G1								

AFTO FORM APR 69 4 PREVIOUS EDITION OBSOLETE

Figure 5 Operating Time Report for Selected Items

MAINTENANCE DATA SYSTEM

Maintainability data were collected by use of the Maintenance Discrepancy/Production Credit Record (AFSC Form 258 and 258-4), figure 6, which was completed by maintenance personnel. All maintenance actions were recorded by maintenance personnel using work unit codes (WUC's) to identify the specific hardware item being worked on and to identify the type of maintenance performed. WUC's were five-digit alpha/numeric codes specified in the WUC Manual (Technical Order 1F-111(B)(Y)A-06), reference 14. The first two digits designated the aircraft system, for example 73 denoted the bombing navigation system (table II). The third digit identified subsystems within the system; for example, 73H denoted the inertial navigation system. The fourth and fifth digits designated assemblies and components within the subsystem; for example, 73HA0 denoted the inertial reference unit (IRU) of the inertial navigation system and 73HAA denoted the parameter memory instrument of the IRU.

Maintenance actions were further defined as support general or nonsupport general maintenance events. Support general maintenance such as preflights, servicing and other schedule maintenance tasks were denoted by WUC's 01XXX through 09XXX. Non-support general maintenance was unscheduled maintenance, such as repair of malfunctions discovered during flight, and were denoted by WUC's 11XXX through 97XXX.

After the AFSC Form 258's were completed by the man who had performed the maintenance, the forms were checked for accuracy by the maintenance supervisor and then system effectiveness personnel at two different levels before being keypunched. The data cards were put through a validation program which checked for errors that had not been previously detected or which had been introduced during keypunching. Computerized cards were output from this program in AF Form 349 (Maintenance Data Collection Record) format so that the maintenance data could be processed through the AFM 66-1 (Maintenance Management) system (reference 15), thus satisfying standard maintenance management requirements. After all detectable errors were eliminated, the data were put into the maintenance master history file. A computerized listing of all input data was edited at two levels in the system engineering section as a final check on data accuracy.

The maintenance data were now on computer tape and could be used for limited maintainability analysis. However, even though the maintenance actions had been documented and entered into the master history file, these actions were often not grouped together as a complete maintenance event. Therefore, all maintenance actions pertaining to a particular malfunction were "bridged" together into one corrective maintenance event. By use of this technique, a much more detailed analysis was possible than would have been permitted using standard maintenance data collection procedures as defined by AFM 66-1. This new maintenance master history file permitted the maintainability analysis conducted during Category II testing and presented in this report.

Form Approved
Budget Bureau No. 21–R251

	A JOB CONTROL NUMBER	B PRI	C TIME SPEC REQD	D WORK AREA	E ESTIMATED MANHOURS	F	1 COPY NR 0 / 2 REPORT NUMBER № 181879
10	3 BASIC WORK CENTER	4 ITEM IDENTIFICATION		5 SERIAL NUMBER	6 TIME CYCLES MILES	7 WHEN DISCOVERED TIME (Day-Mo-Yr-Hours)	
	8 DATE THIS REPORT (Day-Mo-Yr)	9 WORK ORDER NUMBER		10 ORIG REPORT NUMBER	11 WHEN DISC CODE	12 ENG POSN NO	13 ACTIVITY IDENT

FAILED ITEM

	14. MANUFACTURER	15 NOUN - ENGINE TYPE MODEL SERIES MOD		16 SERIAL NUMBER	17 TIME CYCLES/MILES	18 PART NUMBER
20	19 WORK UNIT CODE	20. SYMBOL	21 HOW MAL	22 FEDERAL SUPPLY CLASS	23	24

INSTALLED ITEM

30	25. MANUFACTURER	26. NOUN - ENGINE TYPE MODEL SERIES MOD	27 SERIAL NUMBER	28 TIME CYCLES/MILES	29 PART NUMBER

40 THRU 49

G SUPPLY DOCUMENT NUMBER *(Issue or Demand)*

30. DESCRIPTION OF DISCREPANCY OR MAINTENANCE REQUIRED

H DISCOVERED BY

	31 PREFIX	AFSC	SUF	NR	32. START	33 STOP	34 DELAY CODE	35 START	36 STOP	37 DELAY CODE	38 WORK UNIT CODE	39 ASSISTING WORK CENTER	40 UNITS	41 ACT
50														
51														
52														
53														
54														
55														
56														
57														
58														
59														

60	42. T O NUMBER	43. T O DATE (Day-Mo-Yr)	44. T O PROCEDURE	45. TOOLS/AGE	I CORRECTED BY

61 THRU 69

46 CORRECTIVE ACTION

J INSPECTED BY

K SUPERVISOR	L RECORDS ACTIONS [ ] UNCLEAR DISCREPANCY [ ] REPLACEMENT TIME CHANGE [ ] DATA TRANSCRIBED TO RECORDS	M DATE TRANSCRIBED (Day-Mo-Yr)	N TRANSCRIBED BY

AFSC FORM JAN 66 258 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE **MAINTENANCE DISCREPANCY/PRODUCTION CREDIT RECORD**

Figure 6 Maintenance Discrepancy/Production Credit Record

	47. PIECE PARTS REPLACED DURING REPAIR									
	PART NUMBER	NOUN	WORK UNIT CODE	CIRCUIT SYMBOL	TYPE FAILURE		QTY	HOW MAL	MANUFACTURER	FSC
					PRI	SEC				
70										
THRU										
79										

CODING TO BE IN BLOCKS AS INDICATED

BLOCK 34 AND 37 DELAY CODES

- S AWAITING SUPPLIES AND/OR PARTS
- C DELAY DUE TO CONFLICTING MAINTENANCE
- A WORK STOPPAGE – NON-POWERED AGE OR RPIE
- E WORK STOPPAGE – POWERED AGE OR RPIE
- F FLYING
- P AWAITING PERSONNEL ASSISTANCE
- R ENGINE RUN-UP
- T AWAITING TRANSPORTATION
- X DELAY FOR WEATHER
- K DELAY FOR SPECIAL TEST EQUIPMENT
- M PREPLANNED MAINTENANCE DELAY

BLOCK 41 ACTION CODES

1. SERVICING
2. UNSCHEDULED MAINTENANCE
3. PREFLIGHT INSPECTION
4. POSTFLIGHT INSPECTION
5. HOURLY POSTFLIGHT
6. PERIODIC INSPECTION
7. SPECIAL INSPECTION
8. INDEPENDENT
9. RESEARCH AND DEVELOPMENT

BLOCK 44 T.O. PROCEDURE CODES

1. ADEQUATE
2. INADEQUATE
3. INCOMPLETE
4. MISIDENTIFIED
5. NOT AVAILABLE
6. INCORRECT INFORMATION
7. OTHER

BLOCK 45 TOOLS/AGE CODES

1. TOOLS ADEQUATE
2. TOOLS INADEQUATE
3. TOOLS NOT AVAILABLE
4. TEST EQUIPMENT ADEQUATE
5. TEST EQUIPMENT INADEQUATE
6. TEST EQUIPMENT NOT AVAILABLE
7. TOOLS AND TEST EQUIPMENT ADEQUATE
8. TOOLS AND TEST EQUIPMENT INADEQUATE
9. TOOLS AND TEST EQUIPMENT NOT AVAILABLE

★ GPO 1966 O—789-591

AFSC (AAFB)

Figure 6 Maintenance Discrepancy/Production Credit Record (Concluded)

FUNCTIONAL RELIABILITY FORMULAE

The mission reliability statistics were calculated using the formulae;

$$MFHBFD = \frac{FH}{N_d + N_1 + N_a} \; ; \quad MFHBFL = \frac{FH}{N_1 + N_a} \; ; \quad MFHBA = \frac{FH}{N_a} \qquad (1)$$

where:

- FH = flight hours
- N_d = number of degradations recorded against the subsystem
- N_1 = number of losses recorded against the subsystem
- N_a = number of aborts recorded against the subsystem
- MFHBD = mean flight hours between function degradation
- MFHBFL = mean flight hours between function loss
- MFHBA = mean flight hours between aborts.

The Chi-square (χ^2) distribution using fixed truncation time for the tests was the method used to determine the lower confidence limits for mean flight hour statistics

$$\text{90-percent LCL} = \frac{2\ FH}{\chi^2\ (\alpha,\ 2\ N_f + 2)} \qquad (2)$$

Where:

- FH = flight hours
- N_f = number of no-abort failures
- α = acceptable risk of error (10 percent, 1 - confidence level = 1-90).
- χ^2 = the critical value for the chi-square distribution with risk, , and degrees of freedom, $2\ N_f + 2$.

To calculate the probability that a subsystem would be usable on any mission regardless of duration, the following formulae were used:

$$P_{nd} = \frac{N_s}{N_s + N_d + N_1 + N_a} \qquad (3)$$

$$P_{nl} = \frac{N_s + N_d}{N_s + N_d + N_1 + N_a} \qquad (4)$$

$$P_{na} = \frac{N_s + N_d + N_1}{N_s + N_d + N_1 + N_a} \qquad (5)$$

Where:

P_{nd} = probability of no function degradation

P_{nl} = probability of no function loss

P_{na} = probability of no abort

N_s = number of successful missions recorded for the subsystem.

The 90-percent LCL's for these probabilities were computed using the binomial distribution

$$\sum_{i=N_s}^{N} \binom{N}{i} P^i (1=P)^{N-1} = \alpha$$

Where:

N = sample size

P = LCL probability (90 percent)

α = acceptable risk of error (10 percent)

MAINTAINABILITY FORMULAE

In addition to the nonparametric maintainability statistics computed, the data points obtained were tested by the Kolmogorov-Smirnov (K-S) statistical goodness-of-fit test to determine which of three probability distribution might fit the data. The distributions tested and their mathematical formulation are:

Log normal distribution where t is the time and μ and σ are the distribution parameters,

$$f(t|\mu,\sigma) = \frac{1}{t\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\log_e(t) - \mu}{\sigma}\right)^2}$$

Exponential distribution with the parameter θ,

$$f(t|\theta) = \frac{1}{\theta} e - \frac{t}{\theta}$$

Weibull distribution with parameters θ_1 and θ_2,

$$f(t|\theta_1,\theta_2) = \theta_1\theta_2 t^{(\theta_2 - 1)} e^{(-\theta_1 t^{\theta_2})}$$

REFERENCES

1. Noren, Bruce L., Captain USAF, Category II Systems Test of the FB-111A Navigation and Computer Subsystem, FTC TR-72-32, Air Force Flight Test Center, Edwards AFB, California, August 1972. CONFIDENTIAL.

2. Noren, Bruce L., Captain USAF, and Fordham, Wyndell F., Lieutenant Colonel USAF, Category II Systems Test of the FB-111A Terrain Following Radar (AN/APQ-134), FTC-TR-72-16, Air Force Flight Test Center, Edwards AFB, California, June 1972. CONFIDENTIAL

3. Category II System Test of the FB-111A Armament Subsystem, Air Force Flight Test Center, Edwards AFB, California, to be published.

4. Category II Systems Test of the FB-111A Propulsion Subsystem, Air Force Flight Test Center, Edwards AFB, California, to be published.

5. Category II Systems Test of the FB-111A Flight Control Subsystem, Air Force Flight Test Center, Edwards AFB, California, to be published.

6. Frederick, Paul E., First Lieutenant USAF, and Waller, Robert C., Major USAF, Category II Tests of the F-111 Penetration Aids Subsystem, FTC-TR-71-31, Air Force Flight Test Center, Edwards AFB, California, August 1971. SECRET

7. Blejwas, Thomas E., First Lieutenant USAF, and Boyd, Stuart R., Captain USAF, FB-111A Category II Refused Takeoff Tests, FTC-TR-71-33, Air Force Flight Test Center, Edwards AFB, California, August 1971. UNCLASSIFIED

8. Category II Systems Test of the FB-111A Airframe Secondary Power, Mission and Traffic Control, Environmental Control, and Crew Station Subsystems, Air Force Flight Test Center, Edwards AFB, California, to be published.

9. Noren, Bruce L., Captain USAF, Category II Systems Test of the FB-111A Radar and Navigation Sensor Subsystems, FTC-TR-72-31, Air Force Flight Test Center, Edwards AFB. California, August 1972. CONFIDENTIAL

10. FB-111A Category II Performance Evaluation, Air Force Flight Test Center, Edwards AFB, California, to be published.

11. FB-111A Category II Flying Qualities Tests, Air Force Flight Test Center, Edwards AFB, California, to be published.

12. Category II FB-111A Test Summary, Air Force Flight Test Center, Edwards AFB, California, to be published.

13. FB-111A Flight Manual, T.O. 1F-111(B)A-1, 4 June 1971. UNCLASSIFIED

14. FB-111A Work Unit Code Manual, T.O. 1F-111(B)(Y)A-06, 7 June 1968. UNCLASSIFIED

15. Maintenance Management, AFM 66-1, 10 February 1970. UNCLASSIFIED

16. Maintainability Engineering Analysis Data, FZM-12-6118-3, General Dynamics/Fort Worth, Texas, 31 March 1969. UNCLASSIFIED

17. Reliability Tests Exponential Distribution, MIL-STD-781A, 12 October 1965. UNCLASSIFIED

18. Reliability Program Review, Autonetics Division of North American Rockwell, Anaheim, California, 19 January 1972.

19. Maintainability Specification for Model FB-111A Weapon System, FZM-12-6093A, General Dynamics/Fort Worth, Texas, 30 November 1967. UNCLASSIFIED

BIBLIOGRAPHY

Air Force Systems Command, System Effectiveness Data System, AFSC Form 258/258-4 Maintenance Data Recording Procedures, Maintenance Technical Directive 69-1, Air Force Systems Command, 8 January 1969.

DuBois, N.S. D'Andrea, Jr., Ostrovsky, B.; Arnold, T.S.; et. al., SEDS, System Effectiveness Data System, Volume I, Management Analysis and Program, SAMSO-TR-69-239, Space and Missile Systems Organization (SAMSO), August 1969.

DuBois, N.S. D'Andrea, Jr., Ostrovsky, B.; Arnold, T.S.; et. al., SEDS, System Effectiveness Data System, Volume II, User Documentation and Implementation Instructions, SAMSO-TR-69-240, Space and Missiles Systems Organization (SAMSO), August 1969.

Formatted File System, Summary of Operation, IBM Number N0717, International Business Machines Corporation.

Maintainability Demonstration, MIL-STD-471, Department of Defense, 15 February 1966.

Maintainability Program Requirements (For Systems and Equipments), MIL-STD-470, Department of Defense, 21 March 1966.

Reliability and Maintainability Programs for Systems, Subsystems, Equipment, and Munitions, Air Force Regulation 80-5, Department of the Air Force, 13 December 1969.

Reliability Prediction, MIL-STD-756A, Department of Defense 15 May 1963.

Reliability Program for Systems and Equipment Development and Production, MIL-STD-785A, Department of Defense, 28 March 1969.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY *(Corporate author)* Air Force Flight Test Center Edwards Air Force Base, California	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP N/A

3 REPORT TITLE

Category II FB-111A Reliability and Maintainability Evaluation

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final

5 AUTHOR(S) *(First name, middle initial, last name)*

Neal F. Chamblee
Jan M. Howell

6 REPORT DATE	7a. TOTAL NO OF PAGES	7b. NO OF REFS
September 1972	74	19

8a. CONTRACT OR GRANT NO	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO	FTC-TR-72-33
c. Project Directive 67-1	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	N/A

10 DISTRIBUTION STATEMENT Distribution limited to U.S. Government agencies only (Test and Evaluation), August 1972. Other requests for this document must be referred to ASD (YBT), Wright-Patterson AFB, Ohio 45433.

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
N/A	6510th Test Wing Edwards AFB, California

13 ABSTRACT

This report presents the results of the reliability and maintainability evaluation conducted during the FB-111A Category II test program. The aircraft demonstrated a 1.6-hour mean time between failures and a 1.5-hour mean time between aircrew writeups. The overall aircraft reliability was significantly degraded by the low reliability of the flight controls and most avionics subsystems. The reliability of most non-avionics subsystems was acceptable. The contractor predicted that 23.8 maintenance manhours per flying hour would be required, and 48.0 manhours were actually measured; the difference was attributed to low reliability. Except for excessive removal, bench check, and replacement of good components during troubleshooting, the maintainability of the FB-111A was good. The mode/status lights associated with some subsystems were of questionable value in detecting failures correctly.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
FB-111A aircraft maintainability reliability						

UNCLASSIFIED
Security Classification